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Geology of Kharga-Dakhla Oases Area, Western Desert, Egypt, from Landsat-1 Satellite Images

NASA Landsat G-27930

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abstract

The investigated Kharga-Dakhla Oases area comprises mainly a part of the Western Desert of Egypt covering some 100,000 km² between the following coordinates : Longitude 28°00'E and Latitude 26°00'N, Longitude 33°00'E and Latitude 26°00'N, Longitude 33°00'E and Latitude 25°00'N, Longitude 32°00'E and Latitude 25°00'N, Longitude 32°00'E and Latitude 24°00'N, and Longitude 28°00'E and Latitude 24°00'N.

LANDSAT-1 satellite images interpretation has been carried out in their four spectral bands in black and white transparencies as well as for the false colour composites.

Accordingly, new geological, structural lineation and drainage maps are constructed on a scale of 1 : 500,000. Diagrams and curves for the lineaments of the investigated area are made to help in the understanding of its geological structure. The new maps and studies are elaborated to help the land reclamation projects in the investigated area.

Chapter I

Drainage Geomorphology and Landforms

Drainage and Geomorphology

The general geomorphological features of the area under investigation are found to be closely related to the lithology and structure of the rock exposures, as well as the erosional characteristics of desert regions. The Kharga-Dakhla Oases area is divided into the following main geomorphological units (Fig. 5) :

I. El Shaghab-El Nazzi Hills
II. West Thebes Plateau
III. Kharga Oasis
IV. El Kharafish-Abu Tartur Plateau
V. Dakhla Oasis
VI. West Kharga Oasis Plain.

These geomorphological units are normally well defined and the boundaries among them are established in the reference to the natural geographical features characterizing the investigated area; including the River Nile, the depressions, the plateaux with steep escarpments and the extensive sand sheets.

From the interpretation of LANDSAT-1 satellite images covering the Kharga-Dakhla Oases area, numerous drainage lines have been traced which are of local and regional importance. In the drainage map (Fig. 2), drainage lines are found to form different patterns of variable extension, density and texture according to the prevailing geological, structural and physiological features of the above mentioned geomorphological units of the area.

The new drainage map reveals additional new data as well as some changes in various features of the investigated area when compared to the previously available regional maps of the same area. Among the numerous striking differences which have been visualized on the analysis of LANDSAT-1 satellite images are the following examples :

1. Some changes of the River Nile course have been clearly distinguished, identified and exactly followed.

2. Certain low lands within the depressions of Kharga and Dakhla Oases are filled with water forming shallow lakes and water ponds surrounded by wetlands of moistened soil.

3. The distribution and configuration of cultivated lands both along the studied part of the Nile Valley and in the Kharga and Dakhla Oases have been exactly delineated. Moreover, it has been possible to distinguish between the green and the dry cultivation in March 1973.

4. The sand dune belts have been re-delineated and they appear to have undergone changes in their shape, size and extension, especially due to their migration eastwards by the action of the prevailing northwesternly winds.

Numerous drainage lines have been traced in the new drainage map allover the investigated area showing different patterns according to the regional geological and structural features as well as the prevailing physiographical conditions.

The geomorphological unit to the east of the Nile Valley, namely El Shaghab-El Nazzi Hills, is characterized by a coarse dendritic pattern of wide drainage lines extending from the hilly country in the Eastern Desert westwards to the River Nile.

To the west of Nile Valley, the West Thebes Plateau unit, mainly constituted of limestone, is dissected by thin drainage lines running in various directions. Most of these wadis are long but rather narrow and extending generally in sub-parallel sets. Some of them are draining eastwards to the River Nile, while others represent internal drainage lines within the fractured and gravelly surface of the limestone plateau.

The escarpment overlooking the Kharga Oasis eastwards extends in an almost N-S trend and is intensively dissected by fine dendritic drainage lines arranged in parallel to sub-parallel sets running towards the Kharga Oasis Depression.

Some parallel to sub-parallel long drainage lines with a general E-W trend have been distinguished on El Kharafish-Abu Tartur Plateau. The escarpment, defining the southern boundary of the plateau and in general terms the northwardly limits of the depressions, is intensely dissected by fine parallel drainage pattern extending generally southwards towards the depressions of Dakhla Oasis, Darb El-Ghabari and Kharga Oasis.

The West Kharga Oasis Sandy Plain, covered mainly by various Nubian Sandstone units, shows drainage patterns of several types, densities and directions, but most of them are draining internally. The relatively long more or less E-W drainage lines in this plain are structurally controlled by fractures of the same trend, while the NNW-SSE and the almost N-S lines are generally parallel to the commonly occurring sand dune belts though also appearing to be structurally controlled. Some of these parallel drainage systems are formed of fine and short dendritic tributaries. At the same time, some of the long drainage lines particularly those extending in the NNW-SSE trend are found to occupy the narrow low lands between the longitudinal sand dune belts.

Moreover, the roughly NE-SW drainage present in the northeastern part of the plain under consideration is believed to be related to some axes of fold traces occurring in about the same trend.

Landforms

Kharga Oasis constitutes a natural excavation in the surface of the desert west of the Nile. It is elongated in a N-S direction, and it is bounded on the east, north and partly on the west by precipitious escarpments rising more than 300 m above the oasis floor. Within that depression and also within Dakhla Oasis Depression past wet climate and present prevailing aridity are manifested. The strong hydrographic pattern witnessed in the plateau and in the escarpments, and the dominance of the lacustrine and alluvial deposits, during the prevalence of the wet climatic conditions, indicate that the water action was also operative in the excavation processes of Kharga and Dakhla Oases beside the wind factor, both have acted on a basically favorable tectonic framework.

The morphologic feactures displayed in Kharga Oasis are distinguished into (1) the elevated plateau, (2) the foothill slopes, and (3) the Kharga Oasis Depression.

The elevated plateau is dominated by calcareous rocks belonging mainly to the Early Eocene. It rises to about 350 m above the low lying depression floor, and is dissected by a number of dry wadis directed to the depression. The surface of this plateau is not smooth and it slopes regionally in the eastward direction following the general basinal structural condition to the east. The eastern plateau extends further to the east till it bounds the Nile Basin on the western side. The western plateau rises more than 400 m above the depression floor, and is dominated by Late Cretaceous chalky limestones.

The transition from the plateau to the Kharga Oasis Depression is rapid and is marked by steep escarpments bounding the depression from the east, north and northwest. The southern and western boundaries of the depression are ill-defined and the latter is quite open. These escarpments which represent the foot-hill slopes are occupied by softer beds belonging to the Late Cretaceous. The slopes are developed in the eastern side steps. Low sand dunes are accumulated along the foot of these slopes.

The eastern escarpment runs almost in an N-S direction and is dissected by numerous gullies which are remnants of old drainage lines directed into the depression. In some places, **e.g.** east Bulaq and Baris, this trend is deviated into the ENE-WSW.

The northern escarpment is marked by an upper steep face of white limestone. In the northwest, the slopes are irregular and much broken up. On the western side, the slopes are highly broken into a number of isolated hillocks and are largely covered by sands.

Kharga Oasis Depression is elongated and runs in a N-S direction, and extends eastward to the foot of the escarpment situated at an elevation of +150 m above sea level. The land surface slopes gently towards the axial portion of the depression which is situated along the line extending from El Maharig to Baris, at a rate of about 7 m/km.

Within Kharga Oasis Depression two local sumps exist; one to the northeast of Gebel El Qarn where the elevation is about one meter above sea level and the other exists at Qasr El Zaiyan with a surface elevation of about +7 m.

The surface is dotted by a number of elevated points which break the monotony of the scenery, **e.g.** Gebel Tarif (+430 m), Gebel El Teir (+320 m), Gebel Tarawan (+150 m), Gebel Ghanima (+383 m) and Gebel El Ghanayim (+375 m). The surface is also dotted by a number of low lying hills which are underlain by Nubian Sandstone at El Nadura, El Qarn, El Zaiyan and El Qala.

The axial portion of Kharga Oasis Depression is essentially covered by lacustrine deposits which are developed into extensive flats or occur in the form of isolated hammocks oriented in the N-S direction. These deposits represent the more suitable cultivable land in the depression which is also dominated by local marshes developed due to the misuse of groundwater.

Outside the axial portion and due to its marginal portions, the surface of the depression is almost barren and merges into the extreme desert to the west. Generally, the depression is covered with sand accumulations in the form of crescentic sand dunes and sand sheets.

Dakhla Oasis Depression is bounded on the northern side by a precipitous escarpment which rises some 300 m above the depression floor and which marks the edge of the extensive limestone plateau rising about 400 m above sea level.

Generally, the landscape in Dakhla Oasis is distinguished into : (1) the northern structural plateau, (2) the central piedmont plain, and (3) the southern structural plain.

The northern structural plateau lies to the north of Dakhla Oasis Depression and extends northward to Farafra Oasis. The surface of such plateau is underlain by weathered resistant limestone and slopes

alluvial deposits comprising horizontal gravel terraces are existing. Down stream of these wadis, fan deposits are accumulated.

The plateau constitutes a dead watershed and is dissected by a number of dry drainage lines directed to the depression, **e.g.** Wadi El Battikh, Wadi El Tawil and Wadi Budkhulu. Within these wadis young alluvial deposits comprising horizontal gravel terraces are existing. Down stream of these wadis, fan deposits are accumulated.

The limestone of the plateau surface is underlain by shales and sandstone which constitute the face of the escarpment overlooking Dakhla Oasis Depression to the north. This escarpment runs almost in an E-W direction for about 200 km, but locally it shows a zigzag form, and in this respect it corresponds to minor structural undulations. This phenomenon is responsible for the development of long rocky tongues protruding into the depression. The face of the escarpment is developed in some localities into steps where they form secondary plateaux at lower altitudes.

The piedmont plain represents the low area confined between the foot of the escarpment and the southern structural plain. The surface of this plain is dominated by destroyed lacustrine deposits which are developed into a variety of landforms, **e.g.** elongate hammocks, irregular gullies and barren mud flats.

The northern portion of this plain, which occupies the narrow strip adjacent to the foot of the escarpment, is characterized by its undulating relief. The surface of this portion is barren with regard to vegetation and is dominated by stony soils. This surface is also dotted by few rocky hills which are detached from the plateau, **e.g.** Qaret El Mawhoub (Gebel Edmonstone).

On the other hand, the central portion which occupies much of the Dakhla Oasis Depression runs in an E-W direction, and extends for a distance of about 100 km. This portion rises to 125 m above sea level, with some hillocks rising abruptly from the surface and reaching to +150 m. The surface of this central portion of the piedmont plain is dominated by a variety of younger deposits, **e.g.** lacustrine clays, gravels of alluvial origin, eolian sands and saline deposits. These younger deposits take a variety of landforms which are exemplified by the following :

1. Clay hammocks

Dominating the central portion of the depression, and composed of lacustrine deposits which are dominated by fine sand and gypseous clay.

2. Sand dunes

Existing in the western portion at El Qasr, El Qalamun, El Gidida and Budkhulu. The dunes are arranged into dune ridges which are most-

ly oriented in the NNW-SSE direction, and rise some 10 m above the surrounding surface.

3. Flat playa surface

Constituting the cultivable locations in the depression. Locally portions of such locations are transformed into sabkhas due to the prevailing aridity and the misuse of groundwater.

The structural plain occupies much of the southern extension of Dakhla Oasis Depression, and is underlain by Nubian Sandstone. The surface, rising to more than + 200 m, is occasionally covered by drift sands in the form of extensive sheets. This surface is dissected by dry insequent wadis which are directed to the depression.

From the hydrophysiographical point of view, the elevated plateau in both Kharga and Dakhla Oases acting at present as an almost dead water-shed, was in late Tertiary and early Quaternary a widespread catchment area for local rainfall. The surface runoff water was directed principally to the low depression areas where fresh water lakes were formed. This water added much to the Nubian aquifer potentials, especially the upper shallow aquifer. At the same time, after drying, lacustrine deposits are left behind, these forming now the base of the soil deposits which are under reclamation in the area of investigation. These deposits contain a considerable salt content leached from the exposed strata in the elevated plateau. The ground elevation in the central portion of the depression areas is below the static level of the groundwater, a condition which is responsible for the free flowage of groundwater. Due to this fact and under the present arid conditions, occasional salines and sabkhas have been formed.

Along the stretch between Idfu and Qena, the River Nile passes through a relatively narrow wadi which is bounded on both sides by an elevated plateau. Between Idfu and Esna, this plateau is relatively low and is composed of tabular varicoloured Nubian Sandstone where it varies in height from + 200 m to 300 m with a general gentle dip of 1-3°NW. Due north and northwest of this land stretch, the Nubian Sandstone is covered by soft and easily denuded shaly beds, and the locality is deeply dissected by a network of ravines leaving hammocks, mounds and conical hills. On the west, this sandstone plateau is dissected by some dry wadis and their tributaries, e.g. Wadi Rimidin, Wadi Kheiber and Wadi El Raddah, which join the Nile Valley to the east. These wadis are characterized by the presence of gravelly terraces at levels higher than the wadis floors.

Due north of Esna, the calcareous plateau is developed where the Nubian Sandstone bounding cliffs disappear under young soft shaly beds and Eocene limestone. This calcareous plateau represents elements characterizing the arid regions, i.e. the crest, the scarp and the piedmont. The limestone crest usually withstands denudation forming a cap rock of the highest peaks of the outlier resulting from wadi erosion.

Between north Esna and Qena to the east of the Nile, and mainly south and east of Qena bend, a part of this limestone plateau differs geomorphologically from the rest of the plateau, where it is highly dissected forming a badland area and giving rise to some isolated peaks, e.g. Gebel El Nazzi (+670 m), Gebel Serai (+627 m) and Gebel Abu Had (+595 m). The effect of erosion on the outcropping rock types results in a landscape of desert tables and pedestal rocks. The plateau here is dissected by numerous dry wadis, the most prominent of which are Wadi El Madamud, Wadi Zeidun and further to the north Wadi Qena. Along the slopes of these wadis, gravelly deposits in the form of terraces are existing indicating several erosional and depositional stages governed by changes in the local base level. On the west of the River Nile, the limestone plateau is more prominent and runs continuously bordering in some places the Nile itself, and rising some 400 m above it.

The transition from the plateau into the wadi is marked by vertical cliffs of barren rocks which show differential dissolutions and caves. The foot of these cliffs passes into the low lying flood plain through the piedmont plain, the surface of which is occupied by irregular rock fragments of different sizes, representing successive downwash deposits accumulated during phases of wet climatic conditions.

The lowlands on both sides of the Nile course are occupied by the valley fill deposits which are differentiated into :

1. The Pliocene fluviatile conglomerates, sands and clays deposited at the confluences of the tributaries to the Nile, and existing at elevations reaching +160 m.

2. The Plio-Pleistocene terraces deposits; fringing the escarpments on both sides of the Nile Valley. These are composed of conglomerates interbedded with gypsiferous and calcareous clays, sandstones, laminated shaly sands and mixed gravels and sands with pebbles derived from the Nubian Sandstone, as well as the igneous and metamorphic rocks. The development of these terraces is controlled by changes in the base level, changes in the water volume and load, and changes in the hydrographic system of the Nile.

3. The Holocene Nile silt forming the natural river banks. This Nile silt, constituting the flood plains, is constituted of very finely divided mineral matter, fine quartz sand and organic material, which were deposited by flood waters in the course of recent geological times.

Chapter 2

Structure

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The structural lineation map of the Kharga-Dakhla Oases area (Fig. 3), interpreted from LANDSAT-1 satellite images and corroborated by field investigations, shows many linear elements of structural significance. Some curved lineaments and circular features have been distinguished which are seemingly due to regional folding of the sedimentary cover.

Fractures (Including Faults)

The studied area is dissected by 1510 fracture lines of various attitudes and ages where some of them can be considered as faults when associated with either vertical or horizontal displacements while many other lineations represent joints and fractures. Most drainage lines usually follow the previously mentioned lineaments. Table 1 and Fig. 6 show the distribution according to number of all lineaments in relation to their azimuth direction. It has been found out that there are four predominant sets of lineaments in the investigated area trending N15°W-S15°E representing 13.64% of all lineaments, N5°W-S5°E representing 9.80%, N15°E-S15°W making up 9.54% and N35°W-S35°E forming 8.86% of all lineaments. Some minor sets of lineaments are noticed in the N45°-55°E-S45°55°W and in the E-W trends. However, there are certain significant trends for the distribution of structural lineations in each geomorphological unit (Fig. 5) of the Kharga-Dakhla Oases area. On the other hand, the lineaments are greatly variable in their strike length from less than 1 km to more than 20 km (Table 2, Fig. 7).

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TABLE 1 : Azimuth frequency distribution of lineaments according to their number, in the Kharga-Dakhla Oases crea.

Trend \ Unit	I El Shaghab-El Nazzi Hills		II West Thebes Plateau		III Kharga Oasis		IV El Kharafish-Abu Tartur Plateau		V Dakhla Oasis		VI West Kharga Oasis		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N80°-90°W	3	5.00	28	6.36	7	3.89	13	10.83	7	2.26	7	1.75	65	4.30
N70°-80°W	2	3.33	5	1.14	1	0.56	10	8.33	3	0.96	6	1.50	27	1.79
N60°-70°W	1	1.67	14	3.18	—	—	10	8.33	2	0.65	3	0.75	30	1.99
N50°-60°W	10	16.67	16	3.64	—	—	2	1.67	2	0.65	4	1.00	34	2.25
N40°-50°W	5	8.33	26	5.91	3	1.67	—	—	5	1.61	17	4.25	56	3.71
N30°-40°W	5	8.33	40	9.09	5	2.78	1	0.83	16	5.16	31	7.75	98	6.49
N20°-30°W	7	11.67	13	2.96	6	3.33	6	5.00	20	6.45	75	18.75	127	8.41
N10°-20°W	3	5.00	12	2.73	34	18.88	25	20.84	33	10.65	99	24.75	206	13.65
N 0°-10°W	1	1.67	30	6.82	56	31.11	4	3.33	30	9.68	27	6.75	148	9.80
N 0°-10°E	2	3.33	24	5.46	25	13.89	6	5.00	41	13.23	31	7.75	129	8.54
N10°-20°E	1	1.67	45	10.22	9	5.00	9	7.50	69	22.26	11	2.75	144	9.54
N20°-30°E	2	3.33	27	6.14	8	4.44	5	4.17	31	10.00	8	2.00	81	5.36
N30°-40°E	4	6.67	31	7.04	5	2.78	2	1.67	22	7.10	6	1.50	70	4.64
N40°-50°E	—	—	28	6.36	10	5.56	2	1.67	15	4.84	18	4.50	73	4.83
N50°-60°E	2	3.33	28	6.36	6	3.33	1	0.83	5	1.61	19	4.75	61	4.04
N60°-70°E	5	8.33	25	5.68	—	—	8	6.67	3	0.96	13	3.25	54	3.58
N70°-80°E	3	5.00	34	7.73	4	2.22	6	5.00	1	0.32	10	2.50	58	3.84
N80°-90°E	4	6.67	14	3.18	1	0.56	10	8.33	5	1.61	15	3.75	49	3.25
Total	60	100.00	440	100.00	180	100.00	120	100.00	310	100.00	400	100.00	1510	100.00

TABLE : 2 : Azimuth frequency distribution of structural lineaments, according to their lengths, in the Kharga - Dakhla Oases area.

Trend \ Unit	I El Shaghab-El Nazzi Hills		II West Thebes Plateau		III Kharga Oasis		IV El Kharafish-Abu Tartur Plateau		V Dakhla Oasis		VI West Kharga Oasis		Total	
	km	%	km	%	km	%	km	%	km	%	km	%	km	%
N80°-90°W	44	5.16	322	5.84	31	1.20	149	13.03	37	2.17	252	4.83	835	4.91
N70°-80°W	13	1.52	114	2.07	5	0.19	125	10.93	22	1.29	50	0.96	329	1.93
N60°-70°W	15	1.76	166	3.00	—	—	89	7.78	9	0.53	42	0.81	321	1.89
N50°-60°W	169	19.81	200	3.63	—	—	23	2.01	8	0.47	28	0.54	428	2.51
N40°-50°W	107	12.55	422	7.65	12	0.46	—	—	36	2.11	164	3.14	741	4.35
N30°-40°W	58	6.80	991	17.96	79	3.05	3	0.26	66	3.86	311	5.96	1508	8.86
N20°-30°W	88	10.32	380	6.89	25	0.97	31	2.71	116	6.79	1039	19.92	1679	9.86
N10°-20°W	24	2.81	160	2.90	446	17.23	199	17.40	181	10.60	1281	24.56	2291	13.46
N 0°-10°W	7	0.82	240	4.35	1202	46.44	18	1.57	165	9.66	405	7.77	2037	11.96
N 0°-10°E	20	2.35	191	3.46	504	19.47	26	2.27	200	11.71	256	4.91	1197	7.03
N10°-20°E	10	1.17	345	6.25	59	2.28	32	2.80	476	27.86	102	1.96	1024	6.02
N20°-30°E	17	1.99	129	2.34	61	2.36	22	1.92	181	10.60	69	1.32	479	2.81
N30°-40°E	63	7.39	239	4.33	62	2.40	7	0.61	130	7.61	47	0.90	548	3.22
N40°-50°E	—	—	241	4.37	55	2.13	22	1.92	39	2.28	164	3.14	521	3.06
N50°-60°E	29	3.40	467	8.46	32	1.24	12	1.05	18	1.05	202	3.87	760	4.46
N60°-70°E	93	10.90	280	5.07	—	—	167	14.60	14	0.82	201	3.85	755	4.43
N70°-80°E	28	3.28	366	6.63	12	0.46	68	5.94	1	0.06	217	4.16	692	4.06
N80°-90°E	68	7.97	265	4.80	3	0.12	151	13.20	9	0.53	386	7.40	882	5.18
Total	60	100.00	440	100.00	180	100.00	120	100.00	310	100.00	400	100.00	1510	100.00

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El Shaghab-El Nazzi Hills

This part of the studied area is traversed by lineaments, especially those trending N55°W-S55°E and N25°W-S25°E which show no particular clear displacements. The part of the River Nile passing through the investigated area stretching from Idfu northwards to Qift seemingly coincide with linear elements trending mainly NNW-SSE, N-S and NNE-SSW. These lineaments greatly control the course of the Nile, and even the small sharp kinks encountered in its course. This observation has also been reported before by the same authors along the length of the River Nile from Idfu to South of Aswan (El Shazly, Abdel-Hady, El Ghawaby and El Kassas, 1974 a and 1974 b).

West Thebes Plateau

This part of the investigated area is intensely traversed by many lineaments representing faults and fractures trending in various directions for extensions ranging from 1 km to more than 125 km, though they constitute parallel sets of certain trends. On the basis of their number proportions there are three abundant sets of lineaments trending N15°E-S15°W, N35°W-S35°E and N75°E-S75°W. However, according to their length proportions the three abundant sets of lineaments are those trending N35°W-S35°E, N55°E-S55°W and N45°W-S45°E.

Kharga Oasis

This depression is characterized by the presence of common lineaments representing long faults and fractures trending generally in a N-S direction with slight deviations towards the east or the west. The main sets arranged according to their abundance are those trending N5°W-S5°E, N15°W-S15°E and N5°E-S5°W. The presence of the almost N-S faults and fractures in the Kharga Oasis agrees with the findings of previous workers.

However, the present work, based on the interpretation of LANDSAT-1 satellite images, yields greater number of lineaments, more exact delineation of these lineaments and their greater continuity along their strike in comparison to previous works.

El Kharafish-Abu Tartur Plateau

Lineaments of considerable number and length proportions are common in this plateau and they are found in two main trends of N15°W-S15°E and roughly E-W directions. Moreover, minor sets are also observed in the N60°-80°W-S60°-80°E and N75°E-S75°W trends. One of the important long faults of the WNW-ESE set is that roughly bounding the northwestern part of the escarpment. Another major fault line trending ENE-WSW is nearly coinciding with the trace of the fold axis forming a nose at the western closure of Abu Tartur plateau.

Dakhla Oasis

The most abundant set of lineaments traversing this part of the investigated area is trending N5°15°E-S5°-15°W in a very conspicuous manner, especially along the southern slopes of the escarpment standing along the northern boundary of Dakhla Oasis Depression. Two other sets of lineaments are also common, namely those of N25°E-S25°W and N15°W-S15°E trends. Generally, these lineaments are relatively short and are almost traced in the exposed bed rocks around the plateau. Most of these linear elements are coinciding with parallel sets of fine dendritic drainage lines trending southwards into the Dakhla Oasis Depression.

West Kharga Oasis Plain

This plain is found to be traversed by many linear elements which were not shown in previous publications. The delineated linear elements in this part of the studied area show an abundant set trending in the N15°-25°W-S15°-25°E direction. Moreover, two minor sets have been also observed trending N5°E-S5°W and N35°W-S35°E. Although the almost E-W trending lineaments are few in their number proportion, yet they are extending for some considerable lengths along their strike and representing about 12.23% of the total lengths of lineaments in the considered plain. It is noted that some of the major fault lines and fractures of the almost E-W trend are commonly intensely silicified and ferruginated, thus they form dyke-like bodies as they are more resistant to weathering relative to the surrounding sands and sandstones.

Folds

The curved lineaments delineated by the examination of LANDSAT-1 satellite images are represented mainly by regionally important folds as well as by circular features denoting large-scale domal or basinal structures. Frequency distribution of 310 axes of the delineated folding traces shows the presence of two main groups with their axes trending N55°E-S55°W and N65°W-S65°E, in addition to a less abundant group of N25°E-S25°W trend. These represent 8.06%, 7.42% and 7.10% respectively of the total number of axial traces. Moreover, minor folds have their axes deviating widely around the E-W direction from N80°W-S80°E to N80°W-S80°E to N80°E-S80°W representing altogether about 12.58% of all the axial traces (Table 3 and Fig. 8). Within the investigated Dakhla-Kharga Oases area each geomorphological unit is characterized by certain pattern (Fig. 5).

El Shaghab-El Nazzi Hills

Two main groups of folds have been traced in this part of the investigated area, with their axial traces trending generally in the N25°W-S25°E and N10°-30°E-S10°-30°W directions. The first group is apparently younger and it influences the Early Eocene sediments of Gebel El Nazzi and Gebel Rahmaniya, and these folds are plunging SE with smoothly rounded closures. The second older group is superimposed on the Late Cretaceous rocks to the southeast of Wadi El Shoki and

TABLE 3 : Azimuth frequency distribution of axes of fold traces in the Kharga - Dakhla Oases area.

Trend \ Unit	I El Shoghab-El Nazzi Hills		II West Thebes Plateau		III Kharga Oasis		IV El Kharafish-Abu Tartur Plateau		V Dakhla Oasis		VI West Kharga Oasis		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
N80°-90°W	—	—	20	15.15	1	2.86	2	8.00	1	1.25	—	—	24	7.74
N70°-80°W	—	—	9	6.82	1	2.86	1	4.00	5	6.25	—	—	16	5.16
N60°-70°W	1	4.76	10	7.58	1	2.86	7	28.00	3	3.75	1	5.88	23	7.42
N50°-60°W	1	4.76	2	1.52	1	2.86	2	8.00	3	3.75	—	—	9	2.90
N40°-50°W	2	9.52	8	6.06	2	5.71	—	—	3	3.75	—	—	15	4.84
N30°-40°W	1	4.76	5	3.79	2	5.71	1	4.00	5	6.25	—	—	14	4.52
N20°-30°W	5	23.82	3	2.27	1	2.86	—	—	6	7.50	1	5.88	16	5.16
N10°-20°W	1	4.76	—	—	6	17.14	—	—	3	3.75	2	11.77	12	3.87
N 0°-10°W	—	—	4	3.03	—	—	2	8.00	5	6.25	1	5.88	12	3.87
N 0°-10°E	—	—	6	4.54	4	11.43	1	4.00	6	7.50	2	11.77	19	6.13
N10°-20°E	3	14.29	8	3.79	5	14.28	2	8.00	4	5.00	1	5.88	20	6.45
N20°-30°E	3	14.29	5	3.79	—	—	1	4.00	10	12.50	3	17.65	22	7.10
N30°-40°E	1	4.76	5	6.06	4	11.43	2	8.00	4	5.00	1	5.88	20	6.45
N40°-50°E	2	9.52	5	3.79	—	—	1	4.00	7	8.75	—	—	15	4.84
N50°-60°E	1	4.76	15	11.36	4	11.43	1	4.00	4	5.00	—	—	25	8.06
N60°-70°E	—	—	11	8.33	2	5.71	1	4.00	2	2.50	3	17.64	19	6.13
N70°-80°E	—	—	6	4.54	—	—	1	4.00	5	6.25	2	11.77	14	4.52
N80°-90°E	—	—	10	7.58	1	2.86	—	—	4	5.00	—	—	15	4.84
Total	21	100.00	132	100.00	35	100.00	25	100.00	80	100.00	17	100.00	310	100.00

they are of sinuous plunging type with relatively sharp and tight closures.

West Thebes Plateau

This part of the studied area is characterized by sinuous folding traces extending regionally in the NE-SW and NNW-SSE directions, which reveals two major folding systems with their axial traces trending NW-SE and N85°W-S85°E, respectively. The first folding is manifested in the limestone plateau on the western side of Nile Valley, and it is represented by open folds slightly plunging to S-E. The second folding system is exhibited by regionally extending set of sinuous lineations and crenulations along the eastern escarpment bounding Kharga Oasis Depression which continue further southeastward to join Sin El Kaddab escarpment. Accordingly, this folding is a major one of regional extension and includes some smaller folds represented by minor crenulations of parallel trends. Folds of this set are usually of the open type but slightly plunging to E-S-E. Moreover, some circular structures have been delineated from the LANDSAT-1 satellite images in the West Thebes Plateau. These are represented by doubly-plunging anticlines or sometimes by domal structures superimposed on the Early Eocene limestones, with their long axial traces generally trending in the NNE-SSW direction.

Kharga Oasis

Few curved lineaments are being traced in this part of the investigated area which are superimposed mainly on the Late Cretaceous rock exposures of sandstones and shales-clays belonging to the Nubian Sandstone and El Mahariq Formation. These are generally sinuous open folds having two main axial traces trending in the N-15°W-S15°E and N15°E-S15°W directions and they are slightly plunging to N-W and N.E. respectively. Moreover, some localized minor folds possess oval or circular closures with their axial traces trending mostly N-S. It is noteworthy that there is a great coincidence of the main fault lines and fold axes trending generally N-S in Kharga Oasis Depression. Ghobrial (1967) believes that the NNE-SSW and the NNW-SSE fold axial trends have a compensating effect on each other, thus producing N-S regional general trend.

Field investigations indicate that Kharga Oasis is occupied by three main folding traces trending generally N-S, including a middle, eastern and western one (Fig. 9). The middle folding trace is represented by a series of dissected double plunging anticlinal folds which exhibit curviplanar axial planes and undulating hinge lines. The middle folding trace is nearly continuous from the north of the Kharga Oasis Depression to Garmashin and is often following the same course passing by Gebel El Qarn, Gebel Abu Bayan El Bahari, then extending for some kilometers southwards. The eastern folding trace is represented by a series of dissected double plunging synclines with cur-

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viplanar axial planes and undulating hinge lines. It passes from north to south by Gebel Umm El Ghanayim, Gebel Ghanima, Nagab Esna, Ain Tafnis and continues southwards between Gebel El Qarn and Dush domes for some kilometers. The western folding trace is dissected, and is of double plunging synclinal nature also, with curviplanar axial planes and undulating hinge lines. It passes, from north to south, by El Teir Tarawan, Umm El Nessim, west of Gebel El Qarn, Gebel Abu Bayan El Wastani and extends for some kilometers southwards.

These three main folding traces are often complicated by subsidiary traces of small magnitudes exhibiting the same trend in general. Moreover, greater complications are attained by the latter association with some major faults.

An important structural feature is noticed in the Kharga Oasis part of the investigated area where a series of double plunging anticlines and synclines are located on roughly ENE-WSW lines. The intersection of these fold traces with the N-S folding traces often show domal or basinal structures according to the type of the intersected folds. Chronologically, the ENE-WSW folds are seemingly younger as they dislocate the Early Eocene sediments. These folds are of limited magnitudes when compared with the N-S folds.

El Kharafish-Abu Tartur Plateau

The N65°W-S65°E traces of fold axes represent the only common trend in this part of the investigated Kharga-Dakhla Oases area. This is super-imposed on the Late Paleocene and Early Eocene limestone rocks covering the plateau. Other trends have been also observed but are of minor extensions representing small crenulated lineaments in the eastern side of the plateau with sharp chevron closures plunging eastwards.

Dakhla Oasis

There are two main folding sets traced in the Dakhla Oasis, with their axial traces trending N25°E-S25°W and N45°E-S45°W. Folds of the first set are more abundant and their axial traces generally coincide with the predominating faults and fracture lines traversing this part of the investigated area. These folds are generally of the sinuous type plunging to N-E and their northeastern sides are sharp chevrons while their southwestern sides have a circular closure. This set constitutes a series of alternating minor anticlines and synclines within the major syncline of the Dakhla Oasis. The circular feature imposed on Gebel Edmonstone belongs to this folding which may be represented by a doubly plunging fold. Other curved lineaments have been traced in Dakhla Oasis with axial traces trending N5°E-S5°W and N15°W-S15°E but they are of minor abundance though of similar features to the previously mentioned folds.

West Kharga Oasis Plain

This part of the investigated area is formed mainly of Nubian Sandstone mostly covered with wind-blown sands, and sand dunes and its surface is seemingly highly weathered. Few curved and circular lineaments have been recorded in this plain where the traces of fold axes, though variable, are assuming two main trends in the N25°E-S25°W and N65°E-S65°W directions which represent the relatively older folding in the studied area.

The main structure separating Kharga Oasis from Dakhla Oasis is best manifested in West Kharga Oasis Plain. As mentioned above, the fold axial traces are represented by the N25°E-S25°W and N65° E-S65°W trends. The former fold axial trace is also well represented in El Kharafish-Abu Tartur Plateau northwards of Dakhla and Kharga Oases. The folding with axial traces around the NE-SW direction coincides with the well known Laramide diastrophism acting on the Egyptian territories during the late Cretaceous-early Tertiary. The dominance of the NNW-SSE fractures between Dakhla Oasis and Kharga Oasis is mainly a reflection of the Laramide folding.

Chapter 3

Geology

Introduction

A new geological map for Kharga-Dakhla Oases area (Fig. 4) is constructed on a scale of 1:500,000 from LANDSAT-1 satellite images which shows the following geological units.

Basement

The basement rocks are represented on the geological map of the Kharga-Dakhla Oases area by two units, namely Aswan monumental granite (Fig. 13) and basic rocks associated with it. Both form small bodies outcropping in the vicinity of Abu Bayan locality. In age, Aswan monumental granite is at the boundary between the Precambrian and the Cambrian and it is believed to form the Basement in the investigated area, on which the sedimentary cover has been laid down. On the LANDSAT-1 satellite images, the granite in question is of light grey to bright yellow colour and possesses fine to medium texture. The rock has been previously described by Marrei (1967) and it resembles the porphyritic peralkaline granite with rapakivi texture typical of Aswan area. Most of the exposures at Abu Bayan including Gebel Abu Bayan El Bahari and Gebel Abu Bayan El Qibli are constituted of this granite. However, basic granite associated with partly digested xenoliths of various dimensions of gneisses and schists are out-cropping at Gebel Abu Bayan El Qibli. The latter rocks appear in a relatively darker grey tone and are of coarse irregular surface texture as compared to the normal Aswan monumental granite. However, some xenoliths of small size are abundant in the normal granite.

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Of special significance is the structural setting of the postorogenic granite masses and their spatial distribution in the studied area, where they are found almost in horst-like forms with elongated orientation, scattered along the major fault lines (Fig. 9). The flanks of granite outcrops at Gebel Abu Bayan El Bahari and Gebel Abu Bayan El Qibli are overlain by Nubian Sandstone with dipping angles and directions assuming domal structures, which are confirmed by the presence of double-plunging anticlines (Fig. 14) super-imposed on the Late Cretaceous, Paleocene and Early Eocene sediments exposed to the east of these granite masses, and the synclinal or basinal structure developed at Gebel Abu Bayan El Wastani. The axial traces of these alternating anticlinal and synclinal structures are found to coincide generally with the fault lines trending ENE-WSW along which the granite outcrops are located. These structures are evidently associated with regional uplifting in the southern part of the investigated area leading eventually to the outcropping of the Basement or to its presence at relatively shallower depths as compared to the northern part of the Kharga-Dakhla Oases area.

Sedimentary Cover

Nubian Sandstone

On the LANDSAT-1 satellite images, the Nubian Sandstone could be differentiated into three main members according to their colour tone, texture and surface pattern. However, due to the presence of common intercalations, and the abundance of wind-blown sands and small sand dunes lineating the surface exposures of these members, especially in the West Kharga Oasis Plain, it was sometimes difficult to put sharp boundaries between them and inferred boundaries are delineated instead. On LANDSAT-1 satellite images, the oldest member, namely the White to Purple Sandstone Member, has a light grey to yellowish grey colour and fine to medium texture, sometimes with irregularly scattered patches of darker tone and coarser granular texture possessing the features of the uppermost member of the Nubian Sandstone. The White to Purple Sandstone Member is constituted mainly of white to purple cross-bedded sandstones with thin shale intercalations, and it is well developed in the southwestern sector of the investigated area where its exposures are partly covered with accumulating eolian sands and occasionally showing silicified and ferruginated fractures (Fig. 15). The nearest equivalent to the discussed member is « Abu Bayan Sandstone and Shale Member » given by Awad and Ghobrial (1967) to the basal Nubian Sandstone beds directly overlying the granite at Abu Bayan.

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To the northeast and northwest the White to Purple Sandstone Member is either overlain or is changing laterally into red and purple clays with alternating beds of grey shales and sandy shales, which constitute the Red Clay Member of the Nubian Sandstone. On the LANDSAT-1 satellite images, the latter member has a specific greyish green to medium grey tone and smooth surface of very fine texture. The Red Clay Member is often exposed at Kharga Oasis along some

cores of the double plunging anticlines present in the Oasis. It also occupies the floor of Dakhla Oasis Depression (Fig. 16) surrounding the southern limit of cultivated lands in this oasis.

The topmost delineated unit belonging to the Nubian Sandstone is the Brown Ferruginous Sandstone Member which is constituted of reddish brown to dark cross-bedded ferruginous sandstones with common shale interbeds (Fig. 17, 18 and 19). This member is sometimes capped with black partly quartzitic sandstone (Fig. 20). It is well exposed along the foot-hills of the northern escarpment, around Gebel Taref and Qarn Ginah, and to the south of El Kharafish-Abu Tartur Plateau (Fig. 21). It also forms the topmost beds of the white to purple sandstone hills in the southwestern part of the investigated area. The Brown Ferruginous Sandstone Member appears on LANDSAT-1 satellite images with a characteristic dark grey to greyish black tone, medium to coarse texture and irregular surface. It is sometimes lineated with small sand dunes or striated with wind-blown sands, especially occupying the ravines and fracture lines. The latter sands are generally of light grey to yellowish tone, fine to medium texture, and forming distinctive streaks in contrast to the surrounding rocks, especially along the foot-hills of escarpment and mountain slopes. It is noted that some exposures of the Brown Ferruginous Sandstone Member are surrounded by lighter patches of the White to Purple Sandstone Member, especially in the southwestern sector of the investigated area. The sedimentation of the Nubian Sandstone is terminated in Late Cretaceous.

It is important to correlate the present classification of the Nubian Sandstone and the overlying El Mahariq Formation with the nomenclature used by Hermina, Ghobrial and Issawi (1961) and Hermina (1967) for these geological units. In the first reference, the authors divided Nubian Formation in Dakhla area into two lithologic units, namely a lower Unit I corresponding to the red clays occupying the Dakhla Oasis Depression, and Unit II corresponding to the overlying sandstone, sandy clay and shale. In the second reference, on the geology of the northwestern approaches of Kharga, the author considers the Variegated Shale as the topmost formation of the Nubia Group with the former being essentially constituted of varicoloured claystones, sandy clay and shales, which incorporate the red clays occupying the floor of Dakhla Depression, with interbedded minor sandstone streaks and pockets.

The differences between the present work and those of the previously mentioned authors are due essentially to two reasons. The first one is related to the adopted nomenclature for the geological units, while the second is due to the more detailed nature of the present work. Regarding nomenclature the Variegated Shales or the corresponding El Mahariq Formation should not be considered as a unit of the Nubian Sandstone, as the latter type locality in Nubia does not incorporate the former. So the present approach in this respect is in conformity

with the rules of international stratigraphic nomenclature. Furthermore, the Nubian Sandstone proper is divided into three members in the present work all of them have clays within their sections, but in the middle member the red clay is dominant and, accordingly, it is called the Middle Clay Member. This agrees well with the stratigraphic divisions of the Nubian Sandstone in Aswan area, where the middle member has abundant clay with notable reddish colouration and red hematitic iron ores and it is termed the Iron Ore Member. The Red Clay Member term used, in the present work, in Dakhla-Kharga Oases area corresponds lithostratigraphically to the Iron Ore Member in Aswan area. According to Hermina, Ghobrial and Issawi (1961) and Hermina (1967) all the clays and the intervening sandstone underlying the phosphate unit are lumped together as Unit I or Variegated Shales. In the present work, these are distinguished and mapped as three units, namely El Mahariq Formation corresponding to the proper Qusseir Variegated Shales, and the Brown Ferruginous Sandstone Member and the Red Clay Member corresponding to the upper and middle units of the Nubian Sandstone. The differences between the present work and those of the previous authors do not bear on the importance of the role of the Red Clay in the Kharga-Dakhla Oases area.

Wadi Abbad Formation, El Mahariq Formation

Wadi Abbad Formation represents the clayey shales overlying the Nubian Sandstone and underlying Sibaiya Phosphate Formation along Wadi Abbad on the eastern side of the Nile Valley to the north of Idfu (El Shazly, Abdel Hady, El Ghawaby and El Kassas, 1974-b). In the eastern part of the Kharga-Dakhla Oases area, this formation is exposed between the northern reaches of Wadi Rimidin and Wadi Kheiber, with a relatively limited extension forming an elongated exposure of general NW-SE trend. On the LANDSAT-1 satellite images, Wadi Abbad Formation shows a light to medium grey tone and a medium to coarse granular texture.

El Mahariq Formation is a new formational name of Late Cretaceous age in Kharga and Dakhla Oases which is generally equivalent to Wadi Abbad Formation in the Nile Valley, and Qusseir Variegated Shales in the Red Sea region. Lateral changes in lithology are noted in these generally equivalent formations along the long distances from the Red Sea eastwards to the westward reaches of Kharga-Dakhla Oases area.

El Mahariq Formation is named after its type locality where it is well exposed in the area to the north of El Mahariq village in Kharga Oasis. It is also exposed at Gebel Taref and in the area to the east of El Gaga and Baris villages, as well as along the western flanks of Ain Amur ridge. On the LANDSAT-1 satellite images, the formation in question possesses a medium to dark green colour of greyish tone and fine texture of irregular surface. This formation is generally composed of multi-coloured shales, mostly greenish, brownish and purple,

with thin intercalations of ferruginous siltstone, sandy clay and sandstone beds (Fig. 22).

Sibaiya Phosphate Formation, Kharga-Dakhla Oases Phosphate Formation, Sudr Formation

The phosphate-bearing formations are given different names in the Nile Valley and westwards in Dakhla and Kharga Oases as compared to the Red Sea due to the variable lithologic characteristics of these formations in these main regions of phosphate deposition. While in the Red Sea region the term Gebel Duwi Phosphate Formation is used, in the Nile Valley Sibaiya Phosphate Formation (El Naggar, 1971) is the adopted terminology, while in Kharga and Dakhla Phosphate Formation is introduced. These formations are correlatable, being of Late Cretaceous age but they show wide variations in lithology due to lateral changes in their facies and environments of sedimentation. Further westwards and northwards from Dakhla Oasis, the Kharga-Dakhla Oases Phosphate Formation passes laterally into the Late Cretaceous Sudr Formation constituted of chalk and chalky limestone.

On the LANDSAT-1 satellite images, the Sibaiya Phosphate Formation has a light to medium grey tone and coarse to relatively very coarse texture and granular surface. This formation is widely spread in Wadi Abbad, Sibaiya, Wadi Hegaza and other localities in the Nile Valley. Sibaiya Phosphate Formation is rather thick and it is constituted of phosphate beds separated by dark grey shale, marl, grit and fossiliferous limestone. Its middle horizon is occasionally highly siliceous and containing lenticular bed, nodules and pebbles of chert.

The Kharga-Dakhla Oases Phosphate Formation appears in the LANDSAT-1 satellite images as an elongated strip of medium grey tone and texture. It lies conformably on El Mahariq Formation. The basal bed of the Kharga-Dakhla Oases Phosphate Formation is often constituted of highly fossiliferous phosphatic or phosphate bed as recorded in Gebel El Teir, Gebel Tarawan, Gebel Um El Ghanayem,... etc. It is often present as one bed but sometimes it is exposed as more than one phosphate bed separated by shale, mudstone and poorly phosphatic limestone beds. The latter case is rather clear along the slopes of El Kharafish-Abu Tartur Plateau where the main bed is about 4 m thick being constituted of greyish brown to dark grey phosphates (Fig. 23). Moreover, a hard phosphate bed, 20 cm thick, is recorded in the upper horizon of the discussed formation in the same locality. The lithologic character of this bed is generally similar to the beds of the middle phosphate bearing member of East Luxor phosphate deposits in the Nile Valley (Salman, 1974) with the notable absence of chert in the first. To the northeast of Gebel Edmonstone, the Kharga-Dakhla Oases Phosphate Formation is outcropping along the slopes of some hills where it is composed of two phosphate beds; the lower one is 80 cm thick, yellowish brown, hard, massive and it overlies yellowish brown mudstone bed which incorporates phosphate fragments and a thin phos-

phate band. The main phosphate bed in this locality is overlain by yellowish grey shale chalk veinlets. The upper phosphate bed is 20 cm thick of conglomeratic nature, and is directly capped with chalk and brown massive partly silicious and clayey limestone lenticular beds belonging to Sudr Formation.

Sudr Formation is exposed only in the northwestern part of the studied area, where it is correlatable with the Kharga-Dakhla Oases Phosphate Formation exposed eastwards. However, there is a transitional zone where the two formations are found together with Sudr Formation overlying Kharga-Dakhla Oases Phosphate Formation (Fig. 24). On the LANDSAT-1 satellite images, Sudr Formation could be differentiated into two members. The lower White Chalk Member is the lower unit, it appears on the images as irregular patches with smooth surface of fine texture and a characteristic white colour with bluish tint. It is formed mainly of chalk beds with some intercalations of chalky limestone (Fig. 25).

On the other hand, the upper Brownish Limestone Member is constituted of brownish and greyish massive crystalline limestone which is partly silicified and lenticular. On the LANDSAT-1 satellite images, it has a light grey colour with scattered white spots, and shows medium texture of irregular surface sometimes lineated with small sand dunes and eolian sand accumulations. In some localities, the Brownish Limestone Member is partly covered with lag gravels formed in place from the broken surface of the rock. This feature gives such surfaces in the images a darker tone of grey or greenish colour.

The Lower Esna Formation, Dakhla Formation

This is attributed mainly to the Early Paleocene although its deposition may have been started at the end of the Late Cretaceous. On LANDSAT-1 satellite images, this formation is classified into two members. The lower member shows a dark greyish green tone, granular surface of medium to coarse texture, and it is composed mainly of dark grey to brownish shale with ferruginous mudstone interbeds. The upper member is characterized by its relatively lighter grey to yellowish green colour and smooth surface of fine texture. This member is composed of pale grey shale (Fig. 21) alternating with bands of fossiliferous sandy limestone. These two members are generally equivalent to the « Mawhoub Shale Member » and the « Kharga Shale Member », respectively (Awad and Ghobrial, 1967). From the present geological map (Fig. 4), it is found out that the discussed formation, especially its lower member, is well developed in the eastern side of the studied area, and diminishes northwestwards where its upper member is represented only by some beds forming the outliers of the elongated ridge between Gebel Edmonstone and Qur El Malik.

Gebel Garra Formation, Tarawan Formation

This formation of Paleocene age is essentially formed of chalk, limestone and their intercalations (Fig. 26), as well as some substantial

beds of marl and shale. On the satellite images and in the field, Gebel Garra Formation is divided into a lower Chalk-Chalky Limestone Member and an upper Cavernous, Massive Limestone Member. The lower member has a bright white colour, fine texture and smooth surface, where it is made up essentially of chalk passing into chalky limestone. It forms the top of some mountains in the area such as Gebel Tarawan, Gebel El Teir, Gebel Taref, Gebel Edmonstone and Qur El Malik. The upper member is constituted of cavernous to massive limestone, occasionally with thin bands of marly or siliceous limestone. It appears, on the satellite images, in a whitish to light grey colour with a granular to striated surface of fine to medium texture.

Upper Esna Formation

The stratigraphic position of this formation is at the boundary between Late Paleocene and Early Eocene. It is formed mainly of shale layers with some thin limestone bands and tending to be argillaceous towards the base and calcareous towards the top. The Upper Esna Formation is distinguished on the LANDSAT-1 satellite images by its yellowish green to light brownish grey colour and medium granular texture.

Gebel Serai Formation

This formation is equivalent to Thebes Formation or Luxor Formation of Early Eocene age. It is well developed and widely distributed in the eastern part of the investigated area, where it forms the conspicuous mountains of Shaghab-El Nazzi Hills and the extensive West Thebes Plateau (Fig. 4). According to the LANDSAT-1 satellite images interpretation, confirmed by ground check, this formation is divided into two members equivalent to the previously mapped image units distinguished in West Aswan Area (El Shazly, Abdel Hady, El Ghawaby and El Kassas, 1974-b). The basal member of the Gebel Serai Formation is formed mostly of chalky limestone (Fig. 27) with chert and flint intercalations and it is characterized by its light greenish white colour and smooth surface of fine to medium texture. The upper member of this formation is identified on the images by a relatively darker greenish white colour, medium to coarse texture and granular surface. This member is constituted essentially of massive siliceous and partly caverneous limestone (Fig. 28), occasionally marly or cherty. The exposures of both units of Gebel Serai Formation are sometimes covered with lag gravels imposing some irregular patches of darker greenish grey tone on their surfaces (Fig. 27).

Gebel Qatrani Volcanics

They are mostly represented by some sheets and dykes of Oligocene basalts exposed in the southwestern part of the investigated area. They are found as separate or isolated masses and hills having a conical, oval or hump-shape outcropping in the Nubian Sandstone. The volcanic

activity has been accompanied by hydrothermal solutions giving the ferruginated and silicified zones along some faults and fracture lines acquiring general E-W and ENE-WSW trends in the surrounding Nubian Sanstone. In the satellite images, the basalts are characterized by a black to very dark grey colour with a fine texture and granular surface.

Wadi El Madamud Formation

The Pliocene sediments are represented in the studied area by one formation particularly developed along Wadi El Madamoud on the eastern side of the Nile Valley. It occupies the high terraces of absolute level almost between 200 m and 300 m, capping various older rock units. Wadi El Madamoud Formation is a new formation name given here to some horizons of lacustrine screen deposits, which is probably equivalent to Issawia Formation proposed to extend along the middle reaches of the Nile Valley from Esna to Manfalut (Said, 1971). Two members are distinguished within Wadi El Madamoud Formation. The lower Sand-Clay Member shows a medium grey tone and fine to medium texture with relatively smooth surface. It is constituted mainly of brownish limestone blocks associated with abundant sandy and clayey materials. Exposures of this member are found as small patches overlying older rocks belonging to Sibaiya Phosphate Formation, Upper Esna Formation, and Gebel Serai Formation. The Upper Gravel-Conglomerate Member is very distinct on the LANDSAT-1 satellite images due to its dark grey to brownish grey colour, medium to coarse texture and irregular surface with a dense pattern of minute drainage lines. It forms some isolated occurrences overlying the lower member, as well as some limestone beds of Gebel Serai Formation. It is constituted mostly of limestone pebbles breccia and conglomerate with some sands, clays and shales.

Pleistocene-Holocene Sediments

These sediments have been distinguished on LANDSAT-1 satellite images of the Kharga-Dakhla Oases area into calcite deposits, Darb El Gallaba gravels and silty-clay lake deposits which are partly salty. The calcite deposits form irregular patches of light grey tone and fine texture, exposed in some localities of relatively low level on the West Thebes Plateau. Such calcite deposits may be originally related to late hydrothermal activities of the late Pliocene-early Quaternary, which have been partly mobilized and redeposited under the climatic conditions prevailing in the later Quaternary (El Shazly, Abdel Hady, El Ghawaby and El Kassas, 1974-b).

Darb El Gallaba gravels are found in the southeastern part of the investigated area, representing the northern extension of its large exposure in the West Aswan area (El Shazly **et al.** 1974-b).

The Lake deposits are constituted mainly of horizontally bedded clays, silty-sandy clays and sands with some small and thin salt crusts. They usually contain some scattered patches of natural vegetation,

and sometimes they have a thin cover of eolian sands. Considerable occurrences of these lake deposits have been delineated at some low areas in the floors of Kharga and Dakhla Oases (Fig. 29). They appear on the LANDSAT-1 satellite images in a medium to dark grey tone due to their relatively high moisture content, and they possess fine texture and smooth surface. These lake deposits appear suitable for plant growth as they are already greatly used for cultivation at present.

Holocene Sediments

These include eluvium and terrace deposits, wadi alluvium, Nile alluvium, sand dunes, surficial deposits of eolian sands and sand accumulations, water ponds, sporadic and dense cultivation.

The eluvial deposits are found along the mountain downslopes or as terraces between their foot-hills and the intervening wadis. They show widely different features depending on the original rocks from which they have been derived. The eluvial deposits derived from Late Cretaceous rocks are mostly sandy and clayey having a light grey to yellowish colour on the satellite images. Eluvial deposits derived from Paleocene rocks are mainly constituted of shales sometimes with marl and chalk concretions, and they possess a darker grey tone with scattered light patches due to the variation in their constituents. The eluvial deposits derived from Early Eocene rocks are composed of almost homogeneous calcareous soil having a light greyish-green colour with some dark patches when mixed with gravels and pebbles.

The wadi alluvium distinguished in the Kharga-Dakhla Oases area includes two lithologic units with some variations along themselves. In the upper reaches of most wadis, the filling materials are generally sandy and sometimes gravelly, having medium grey colour and medium to coarse texture of irregular surface. On the other hand, the lower parts of many wadis are mostly covered with clayey to limy soil of lighter grey tone and finer texture.

Nile alluvium, occupying the wide plain on both sides of the cultivated lands of the Nile Valley, is constituted mainly of clay, silt and sandy material which appears on the satellite images in a light grey tone and very fine texture of smooth surface with widely spaced long drainage lines.

The sand dunes in the Kharga-Dakhla Oases area can be differentiated on the LANDSAT-1 satellite images into two units. The first one is of local extension, mostly of crescent type having relatively small dimensions, they are commonly associated with eolian sands; and show yellowish grey colour and fine to medium textures. Heaps of sands forming such dunes are found in the depression of Kharga Oasis, especially near Baris and surrounding Ginah as well as those to the east of Gebel El Teir. In the Dakhla Oasis, they cover the area to the west of Gebel Edmonstone and some parts along Darb El Ghabari.

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The second unit of sand dunes is generally of elongate type forming very long and extensive belts which are extending further northwards and southwards outside the mapped area. These sand dune belts have certain directional trends, mostly NNW-SSE with some deviations to NW-SE or N-S directions. Statistical analysis for the number and length proportions of the various directional trends of the main sand dune belts has been carried out for those delineated from LANDSAT-1 satellite images of March 1973 and compared with the analysis of belts shown on the previous maps published on similar scale during 1928 and 1943 (Table 4 and Fig. 10). This study revealed a general eastward movement of the main sand dune belts in the area, with an average of about 10° difference over more than 45 years, which may be mostly due to cyclic seasonal variation in the prevailing wind direction or to the greater eastward movement of the northern parts of the dune compared to its southern parts. It is noticed that most of the sand dune belts in the Kharga-Dakhla Oases area are southwardly ended almost at topographic contour of 400 m absolute level, or they are stopped at the northern foot-hills of some mountains such as at Gebel Taref and Gebel Abu Bayan El Wastani.

At their southern limbs most of the sand dune belts are bifurcating in an interfingering structure with the exposed rocks, indicating their shallowness at these places and recent accumulation in this direction.

The surficial deposits, eolian sands and sand accumulations cover vast extensions in the western and southwestern parts of the investigated area. The western side of the area is covered with thick sand accumulations and a wide sand dune belt constituting a part of the known Great Sand Sea which is extensively developed westwards. Also, surficial deposits of eolian sands constitute the filling materials in-between the major sand dune belts. Moreover, they may include some small dunes of relatively small and limited dimensions. These sediments are considered as recently transported sands from the surrounding sand dune belts and from the disintegration products of the surrounding Nubian Sandstone and other formations subjected to erosion and wind action. On the LANDSAT-1 satellite images, the locations covered by these sediments have generally a light yellow colour and fine texture, sometimes with greyish tone and medium texture due to variation of their source rocks.

Some small and shallow lakes and water ponds have been identified accurately on the LANDSAT-1 satellite images, where they occupy some of the relatively low parts within the depressions of the Kharga and Dakhla Oases. These water bodies have a notable configuration and orientation where they are arranged nearly along some structural lineations, especially along fractures and faults, and also parallel to the depressions boundaries.

Dense cultivation along the encountered part of the Nile Valley, and sporadic cultivation in the newly reclaimed lands around it and

TABLE 4 : Comparison of the Azimuth frequency distribution of the main sand dune belts on different maps of the Kharga - Dakhla Oases area.

Trend \ Map	Topographical, Survey Dept., 1928 1:500,000				Topographical, Survey Dept., 1942 1:500,000				Geological, Present Work, LANDSAT-1 Images, March 1973, 1:500,000			
	Number		Length		Number		Length		Number		Length	
	No.	%	Km	%	No.	%	Km	%	No.	%	Km	%
N50°-60°W	—	—	—	—	—	—	—	—	3	1.82	15	0.87
N40°-50°W	—	—	—	—	4	1.82	15	0.82	2	1.21	10	0.58
N30°-40°W	3	1.87	37	2.30	6	2.73	35	1.92	6	3.64	48	2.77
N20°-30°W	40	25.00	267	16.56	16	7.27	115	6.31	19	11.52	164	9.47
N10°-20°W	59	36.88	731	45.35	37	16.82	400	21.94	32	19.39	389	22.46
N 0°-10°W	32	20.00	397	24.63	81	36.82	768	42.13	45	27.27	657	37.93
N 0°-10°E	14	8.75	96	5.95	43	19.55	336	18.43	30	18.18	274	15.82
N10°-20°E	8	5.00	70	4.34	16	7.27	80	4.39	15	9.09	91	5.25
N20°-30°E	1	0.63	4	0.25	7	3.18	31	1.70	9	5.46	69	3.98
N30°-40°E	3	1.87	10	0.62	3	1.36	15	0.82	2	1.21	6	0.35
N40°-50°E	—	—	—	—	4	1.82	13	0.72	2	1.21	9	0.52
N50°-60°E	—	—	—	—	3	1.36	15	0.82	—	—	—	—
Total	160	100.00	1612	100.00	220	100.00	1823	100.00	165	100.00	1732	100.00

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dispersed cultivation in the Kharga and Dakhla Oases, have been accurately delineated on the map. The sporadic cultivations are generally of lighter tone and less density than the dense cultivations. It has been also possible to distinguish on the LANDSAT-1 satellite images of March 1973 between the green and dry cultivations.

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Fig. (29) : Lake deposits with a remarkable erosion effect, about 10 km north of El Kharga town.

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الملخص

يختص هذا البحث بدراسة منطقة الواحات الخارجة ـ الداخلة التى تقع اساسا بالصحراء الغربية الجنوبية من جمهورية مصر العربية . وتغطى هذه المنطقة مساحة تبلغ زهاء مائة الف كيلومتر مربع تحدها خطوط الطول والعرض الآتية :

خط طول ٢٨ر٥ شرقا	وخط عرض ٢٦ر٥ شمالا
خط طول ٣٣ر٥ شرقا	وخط عرض ٢٦ر٥ شمالا
خط طول ٣٣ر٥ شرقا	وخط عرض ٢٥ر٥ شمالا
خط طول ٣٢ر٥ شرقا	وخط عرض ٢٥ر٥ شمالا
خط طول ٣٢ر٥ شرقا	وخط عرض ٢٤ر٥ شمالا
خط طول ٢٨ر٥ شرقا	وخط عرض ٢٤ر٥ شمالا

وقد استخدمت صور القمر الصناعى الامريكى لاندسات ـ ١ فى مجالاتها الضوئية الاربعة وفى خليط من هذه المجالات مع بعضهما البعض . كما أجريت كذلك عمليات المسح الحقلى الجيولوجى . وقد جمع من كل ذلك خرائط جيولوجية وتركيبية ، وصرفية لمنطقة الواحات الخارجية ـ الداخلة على مقياس ١ : ٥٠٠ر٠٠٠ ، اعطت صورة اكثر دقة وتفصيلا للمنطقة بالمقارنة بالخرائط السابقة . وعلاوة على ذلك فقد تم القيام بدراسات احصائية للتراكيب الخطية بالمنطقة الممسوحة ادت الى تفهم التركيب الجيولوجى لها .

وقد اعدت الدراسات والتقارير عن منطقة الواحات الخارجة ـ الداخلة بهدف دفع عجلة مشروعات تعمير الصحارى بها .

جيولوجية منطقة الواحات الخارجة - الداخلة - الصحراء الغربية، جمهورية مصر العربية باستخدام صور القمر الصناعي لاندسات-١

استاذ دكتور الشاذلى محمد الشاذلى

نائب رئيس هيئة الطاقة الذرية ورئيس قسم الجيولوجيا والخامات الذرية ، ومدير المجموعة الجيولوجية بمركز الاستشعار من البعد ـ القاهرة

أستاذ دكتور محمد احمد عبد الهادى

أستاذ الهندسة المدنية بجامعة ولاية أوكلاهوما بالولايات المتحدة الامريكية ومدير مركز الاستشعار من البعد ـ القاهرة

دكتور محمد محمد الشاذلى

أستاذ باحث مساعد بمعهد الصحراء ـ المطرية ، باحث بمركز الاستشعار من البعد ـ البعد

دكتور ابراهيم القصاص
دكتور عبد العاطى بدر سليمان
ودكتور حسن الامين

جيولوجيون بقسم الجيولوجيا والخامات الذرية بهيئة الطاقة الذرية ، وباحثون بمركز الاستشعار من البعد ـ القاهرة

جيولوجى احمد عبد الله عبد المجيد

قسم الجيولوجيا والخامات الذرية بهيئة الطاقة الذرية ، باحث مساعد بمشروع الاستشعار من البعد ـ القاهرة

الناشر
مركز الاستشعار من البعد ،
اكاديمية البحث العلمى والتكنولوجيا ،
١٠١ شارع قصر العينى ،القاهرة ،
جمهورية مصر العربية

فبراير سنة ١٩٧٦

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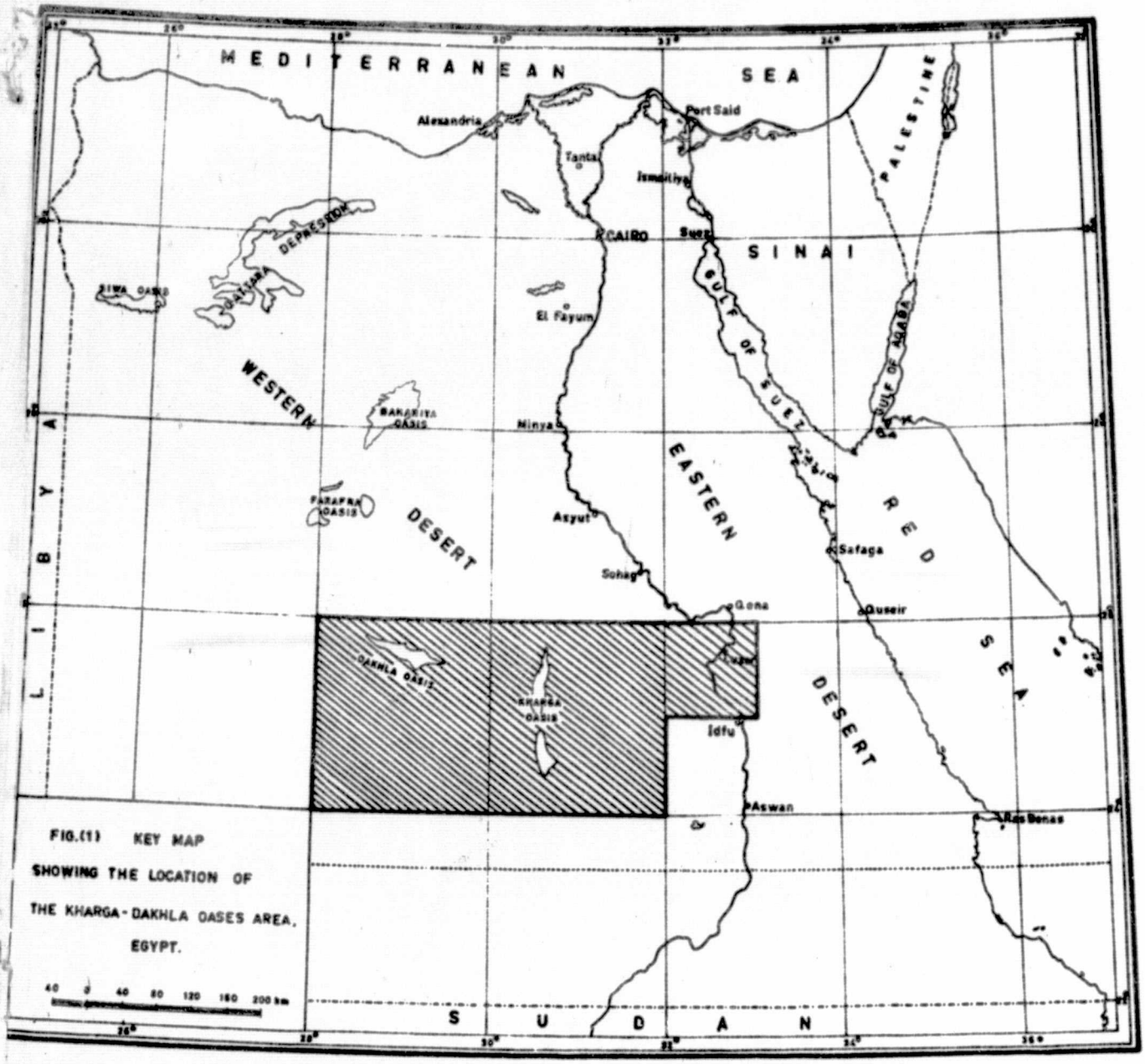

FIG.(1) KEY MAP SHOWING THE LOCATION OF THE KHARGA-DAKHLA OASES AREA, EGYPT.

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FIG. (2) GENERAL DRAINAGE MAP OF THE KHAR

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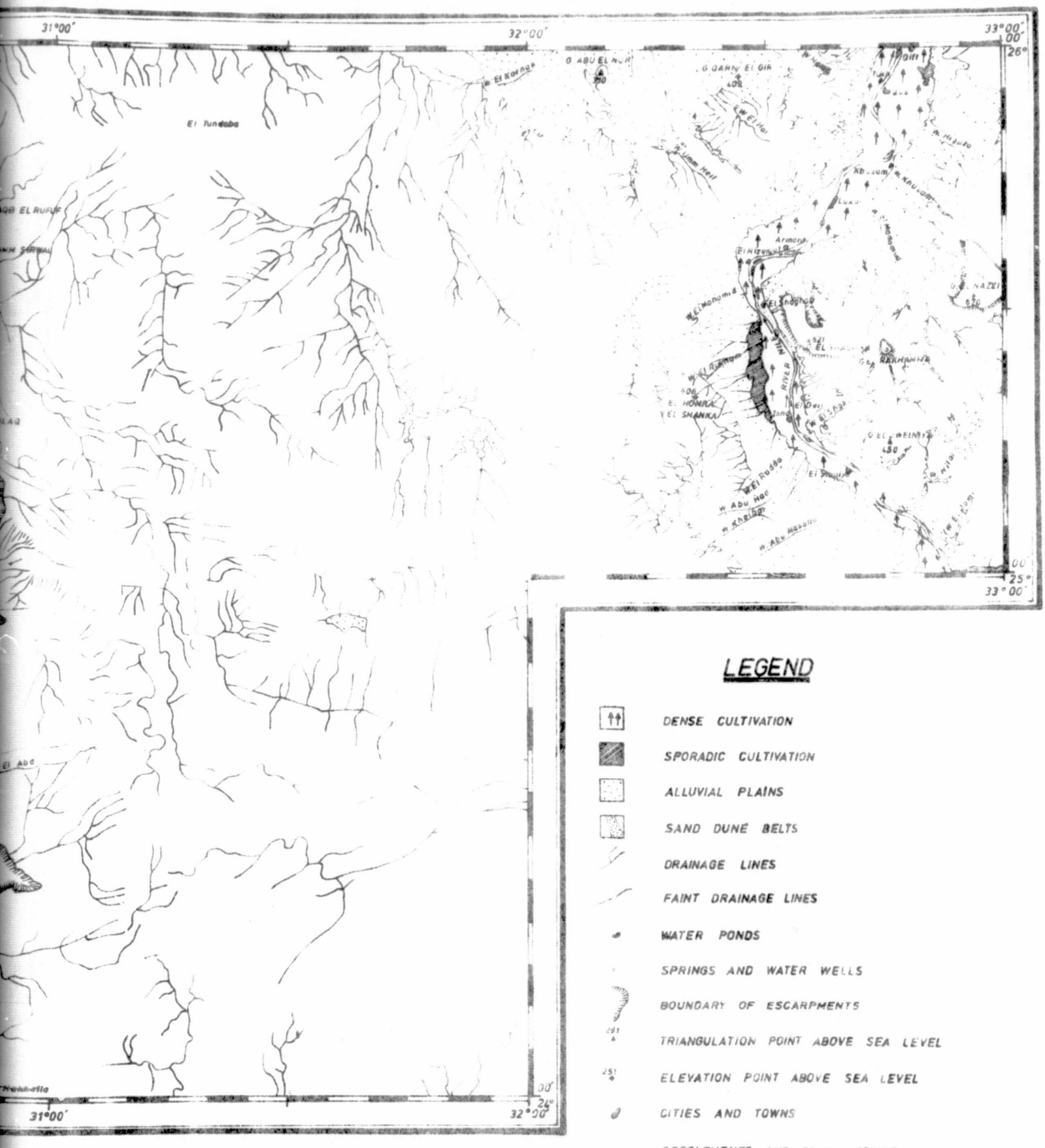
RAINAGE MAP OF THE KHARGA - DAKHLA OASES AREA, EGYPT.

(FROM LANDSAT - 1 SATELLITE IMAGES, 1973)

20 15 10 5 0 10 20 30 40 50 60 70 80 90 100 km

FOLDOUT FRAME 3



LEGEND

- DENSE CULTIVATION
- SPORADIC CULTIVATION
- ALLUVIAL PLAINS
- SAND DUNE BELTS
- DRAINAGE LINES
- FAINT DRAINAGE LINES
- WATER PONDS
- SPRINGS AND WATER WELLS
- BOUNDARY OF ESCARPMENTS
- TRIANGULATION POINT ABOVE SEA LEVEL
- ELEVATION POINT ABOVE SEA LEVEL
- CITIES AND TOWNS
- SETTLEMENTS AND SMALL TOWNS

REA, EGYPT.

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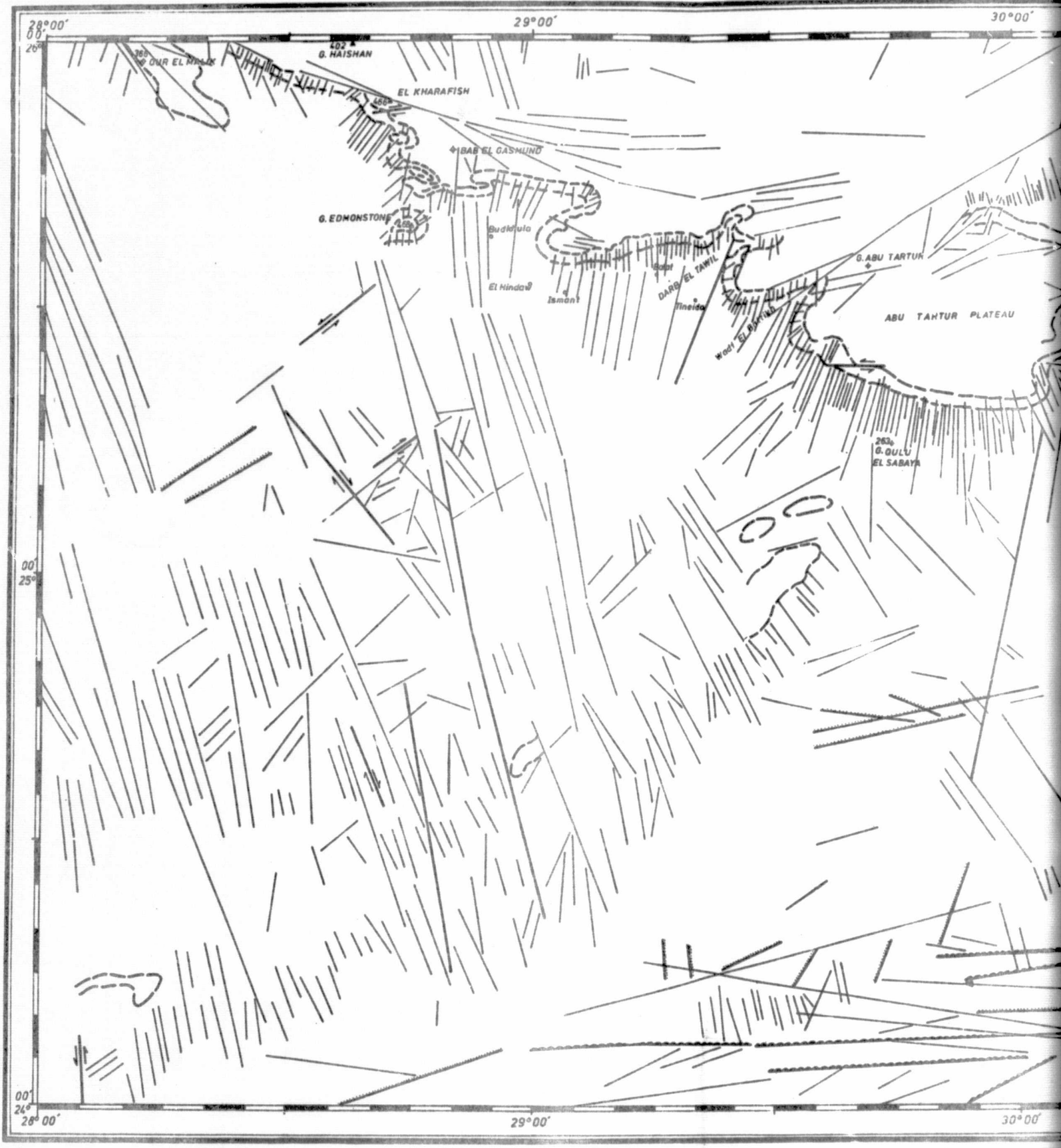
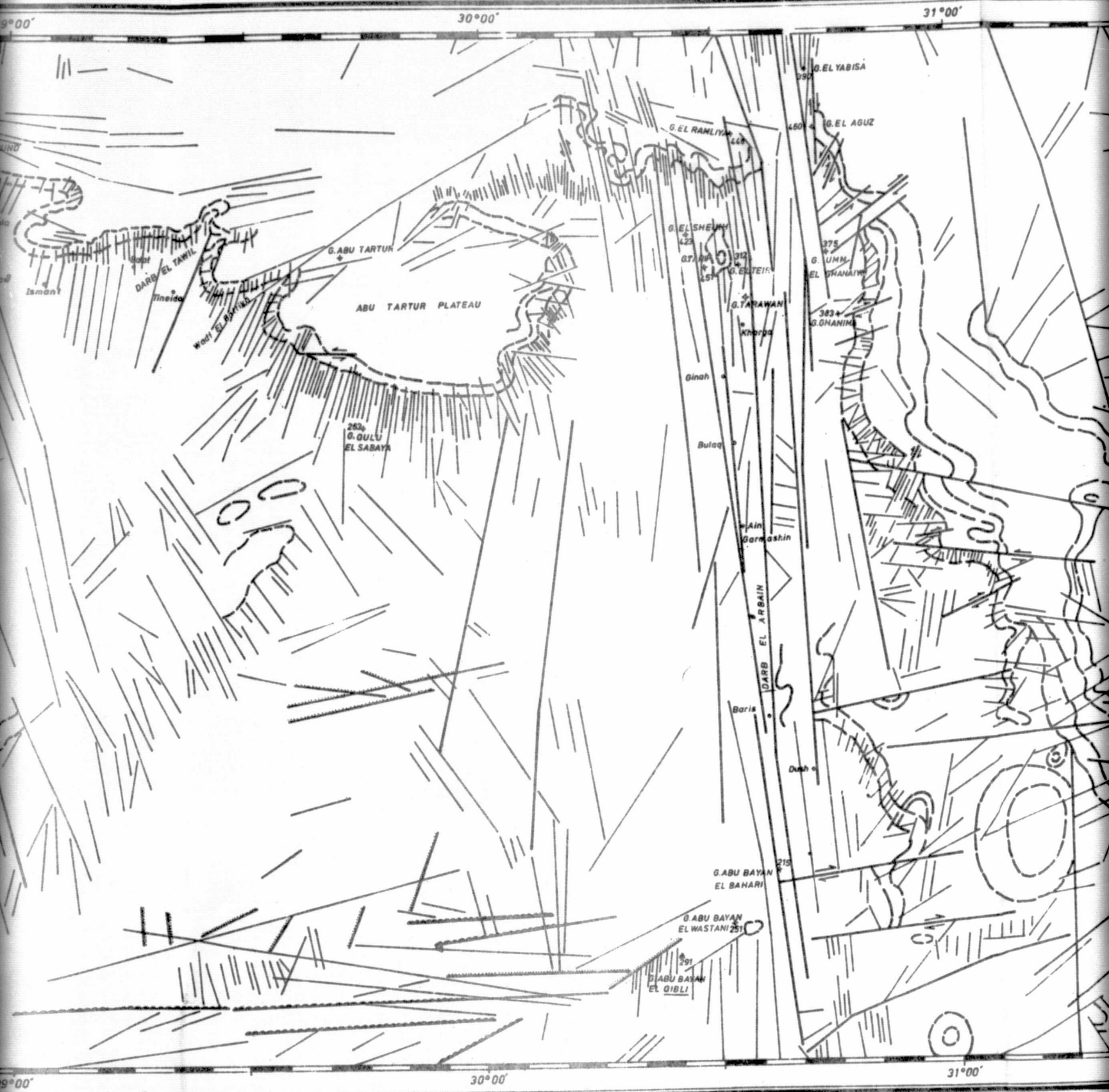


FIG. (3) STRUCTURAL LINEATION MAP OF THE KH

PROJECT
ECHNOLOGY

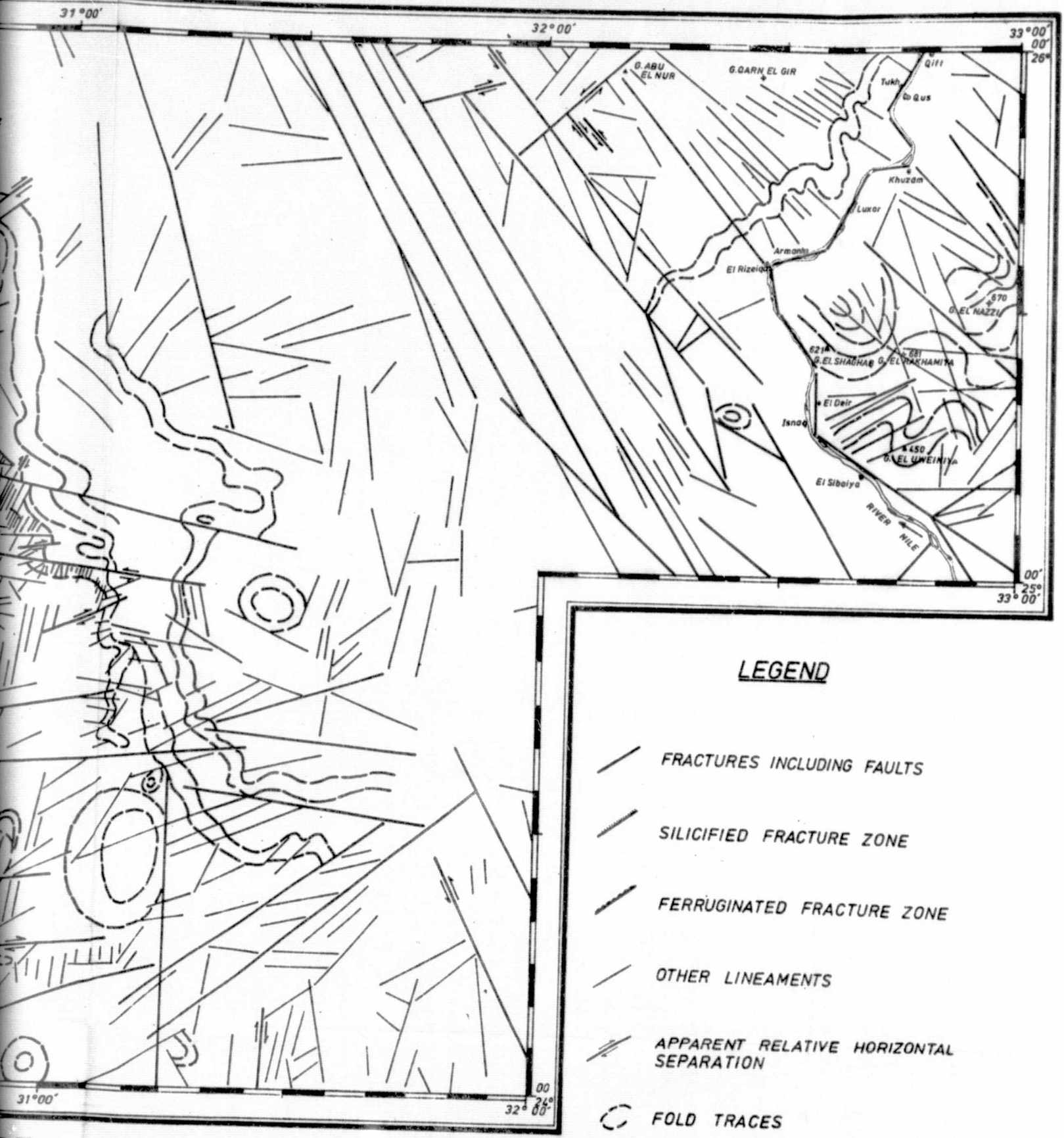


RAL LINEATION MAP OF THE KHARGA - DAKHLA OASES AREA, EGYPT

(FROM LANDSAT - 1 SATELLITE IMAGES, 1973)

20 15 10 5 0 10 20 30 40 50 60 70 80 90 100 km

GEOLOGY FRAME 3



REA, EGYPT

INDEX FRAME

OSU - REMOTE SENSING RESEARCH PROJECT

ACADEMY OF SCIENTIFIC RESEARCH AND TCHNOLOGY

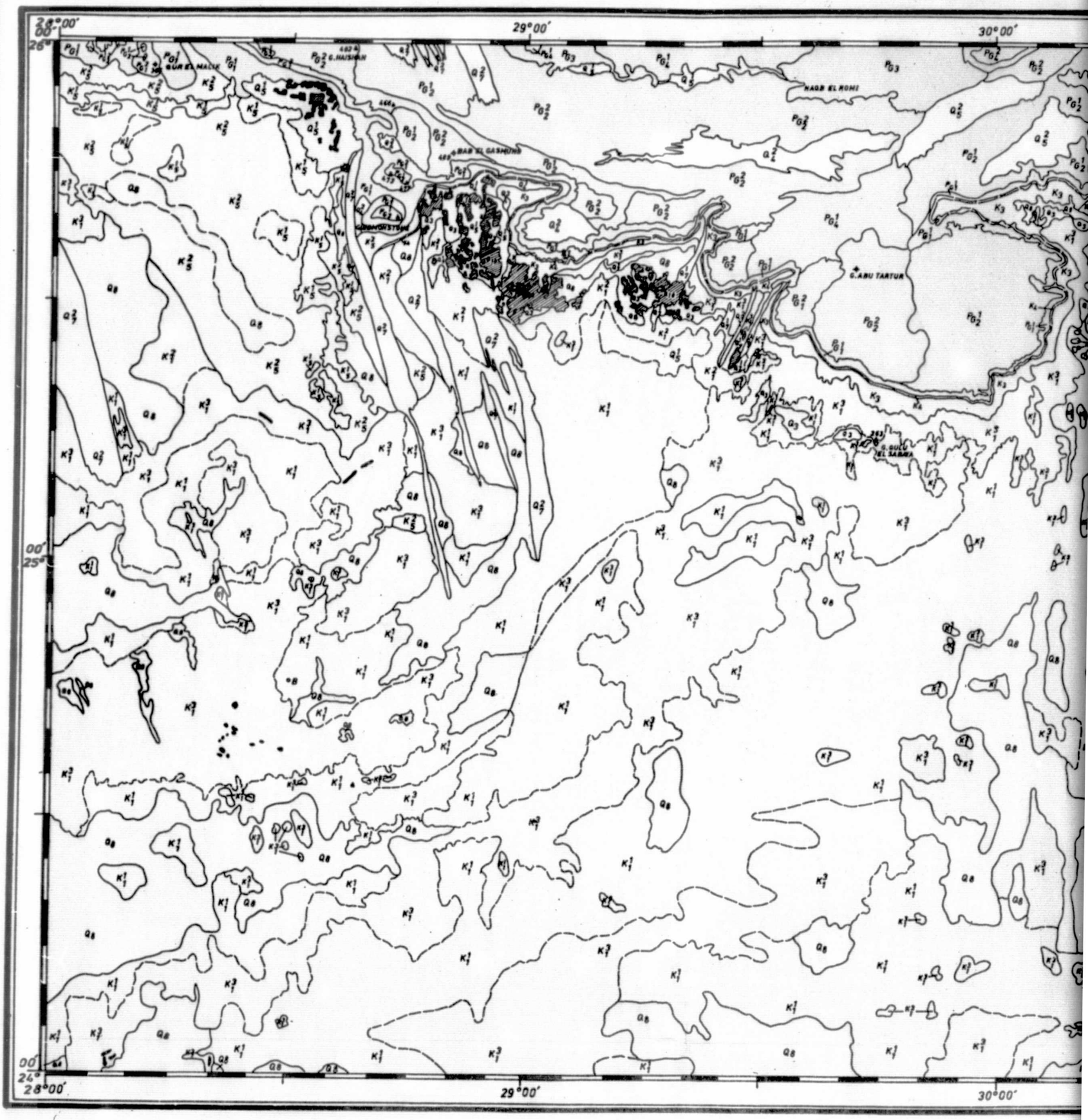
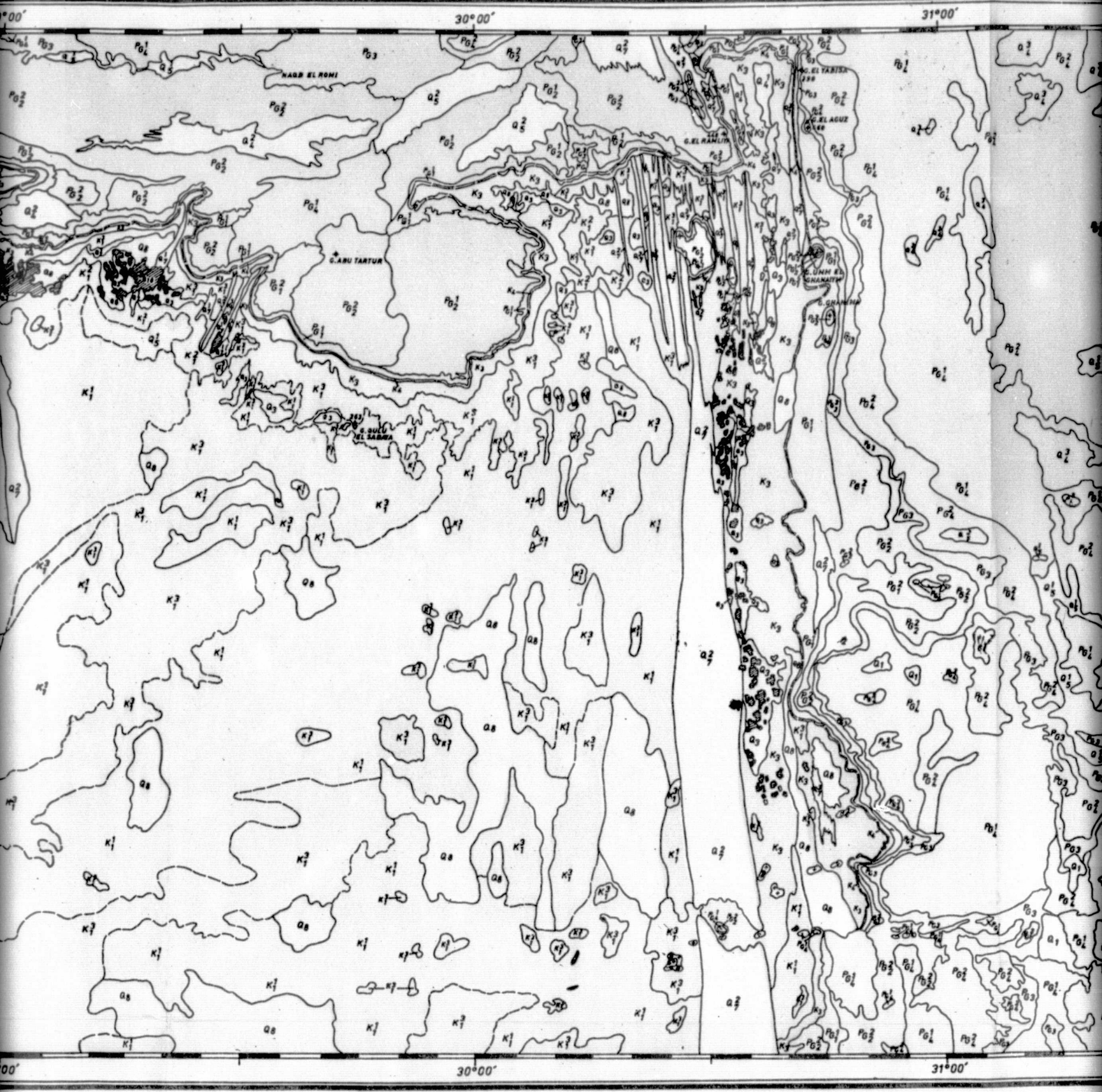


FIG.(4) GEOLOGICAL MAP OF THE KHARGA - D

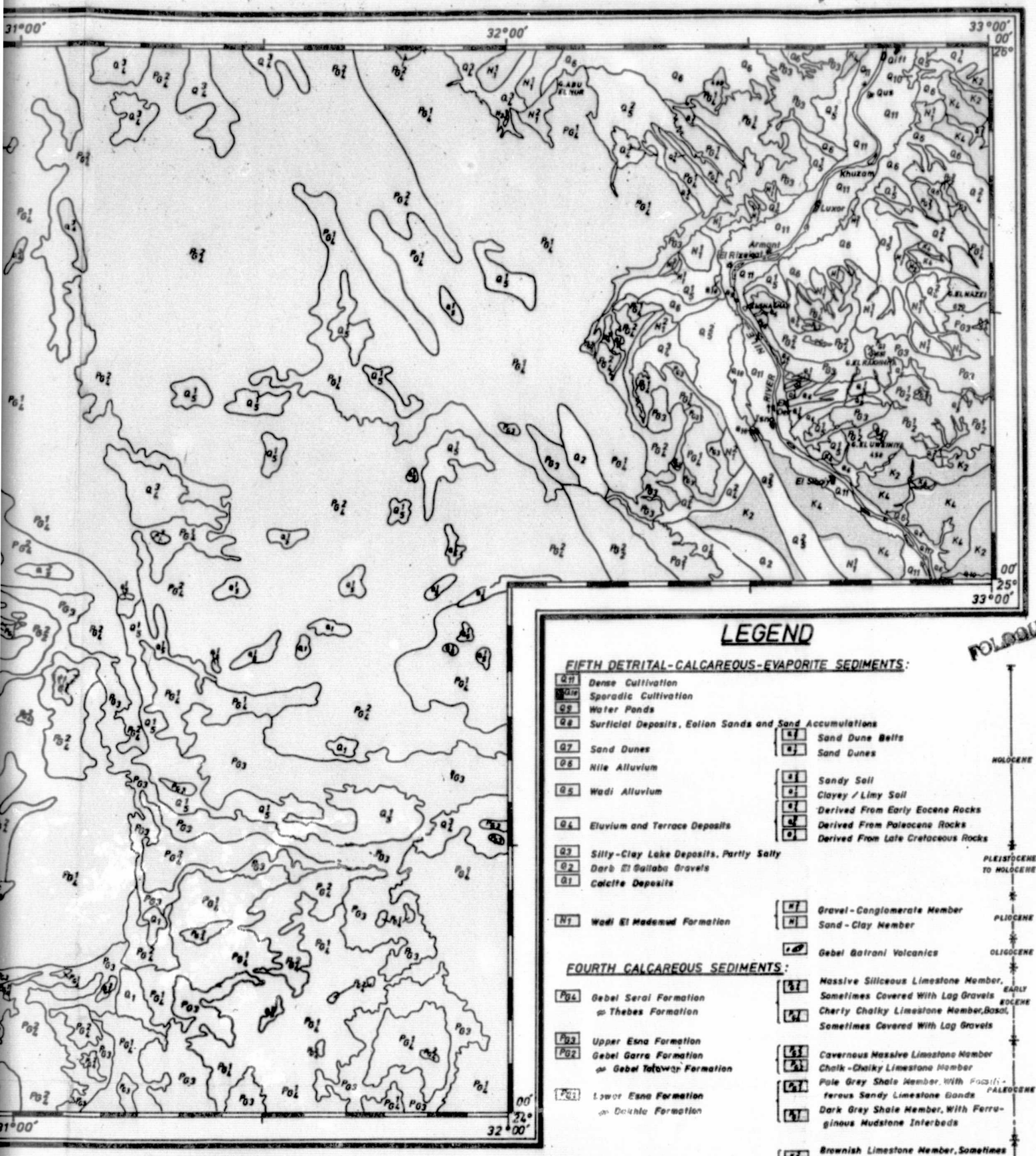
FRAME



OLOGICAL MAP OF THE KHARGA - DAKHLA OASES AREA, EGYPT.

(FROM LANDSAT-1 SATELLITE IMAGES, 1973)

20 15 10 5 0 10 20 30 40 50 60 70 80 90 100 km



LEGEND

FIFTH DETRITAL-CALCAREOUS-EVAPORITE SEDIMENTS:

- Q11 — Dense Cultivation
- Q10 — Sporadic Cultivation
- Q9 — Water Ponds
- Q8 — Surficial Deposits, Eolian Sands and Sand Accumulations
- Q7 — Sand Dunes
  - a_5^1 Sand Dune Belts
  - a_5^2 Sand Dunes
- Q6 — Nile Alluvium
- Q5 — Wadi Alluvium
  - a_4^1 Sandy Soil
  - a_4^2 Clayey / Limy Soil
- Q4 — Eluvium and Terrace Deposits
  - a_3^1 Derived From Early Eocene Rocks
  - a_3^2 Derived From Paleocene Rocks
  - a_3^3 Derived From Late Cretaceous Rocks
- Q3 — Silty-Clay Lake Deposits, Partly Salty
- Q2 — Darb El Gallaba Gravels
- Q1 — Calcite Deposits
- N_1 — Wadi El Hadaswd Formation
  - N_1^2 Gravel-Conglomerate Member
  - N_1^1 Sand-Clay Member
- Gebel Gatrani Volcanics

FOURTH CALCAREOUS SEDIMENTS:

- Pg_4 — Gebel Seraf Formation ⇔ Thebes Formation
  - Pg_4^2 Massive Siliceous Limestone Member, Sometimes Covered With Lag Gravels
  - Pg_4^1 Cherty Chalky Limestone Member, Basal, Sometimes Covered With Lag Gravels
- Pg_3 — Upper Esna Formation
- Pg_2 — Gebel Garra Formation ⇔ Gebel Tatawin Formation
  - Pg_2^2 Cavernous Massive Limestone Member
  - Pg_2^1 Chalk-Chalky Limestone Member
- Pg_1 — Lower Esna Formation ⇔ Dakhla Formation
  - Pg_1^2 Pale Grey Shale Member, With Fossiliferous Sandy Limestone Bands
  - Pg_1^1 Dark Grey Shale Member, With Ferruginous Mudstone Interbeds
- K_5 — Sudr Formation
  - K_5^2 Brownish Limestone Member, Sometimes Covered With Lag Gravels
  - K_5^1 White Chalk Member
- K_4 — Kharga-Dakhla Oases Phosphate Formation · Sibaiya Phosphate Formation

THIRD DETRITAL SEDIMENTS:

- K_2 — Wadi Abbad Formation
  - K_2^3 El Maharig Formation
  - K_2^2 Brown Ferruginous Sandstone Member, Sometimes Lineated With Small Sand Dunes, and Sometimes With K_2^1
  - K_2^2 Red Clay Member
  - K_2^1 White to Purple Sandstone Member, Sometimes With K_2^2
- K_1 ⇔ Nubian Sandstone

POST OROGENIC PLUTONITES:

- Aswan Monumental Granite
- Basic Rocks Associated With Aswan Monumental Granite

Sharp Geological Contact — Inferred Geological Contact

QUATERNARY: HOLOCENE; PLEISTOCENE TO HOLOCENE
TERTIARY: PLIOCENE; OLIGOCENE; EARLY EOCENE; PALEOCENE
PALEOGENE
CRETACEOUS: LATE CRETACEOUS
CAMBRIAN PRECAMBRIAN

EGYPT.

OSU-REMOTE SENSING RESEARCH PROJECT

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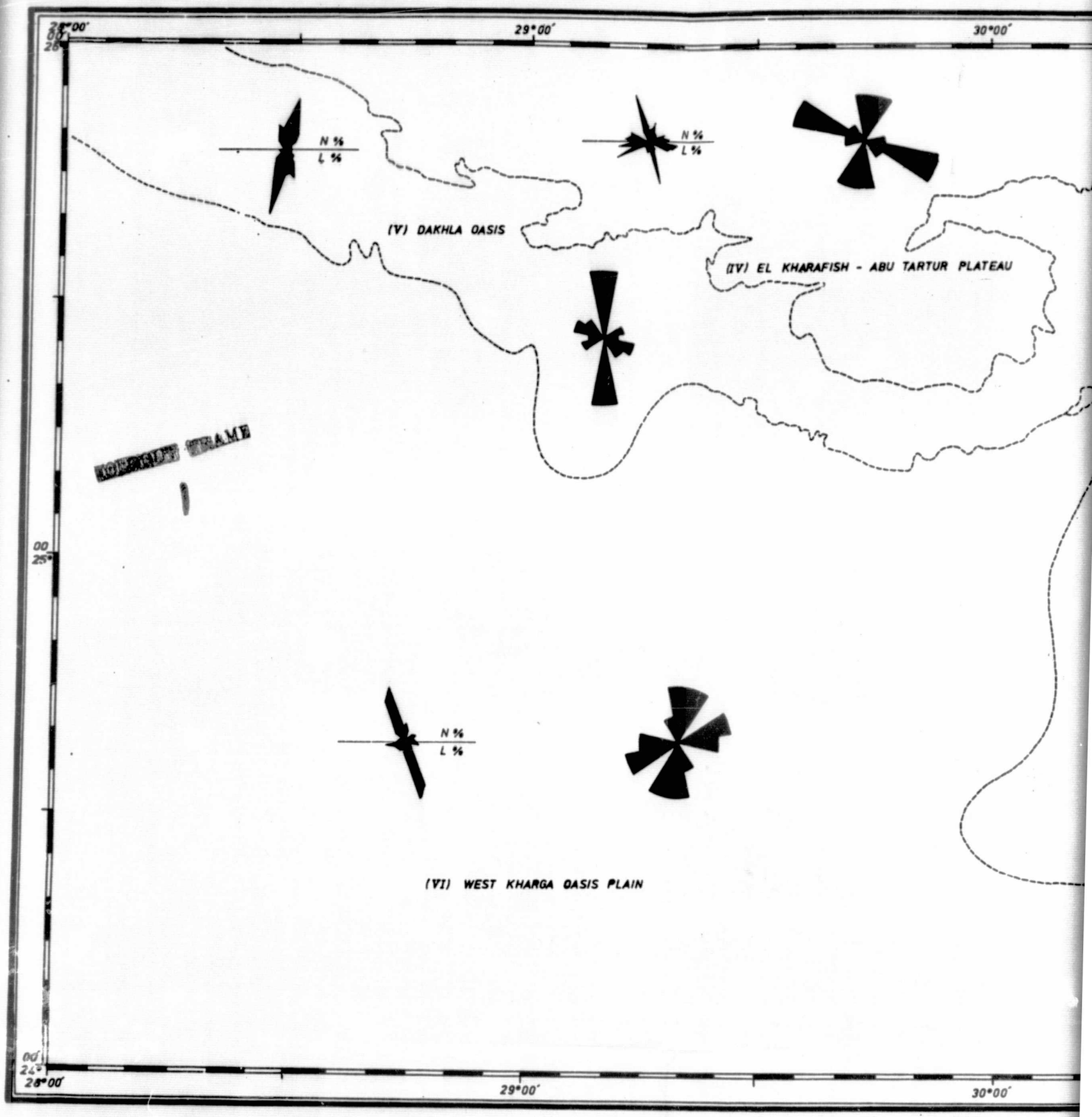


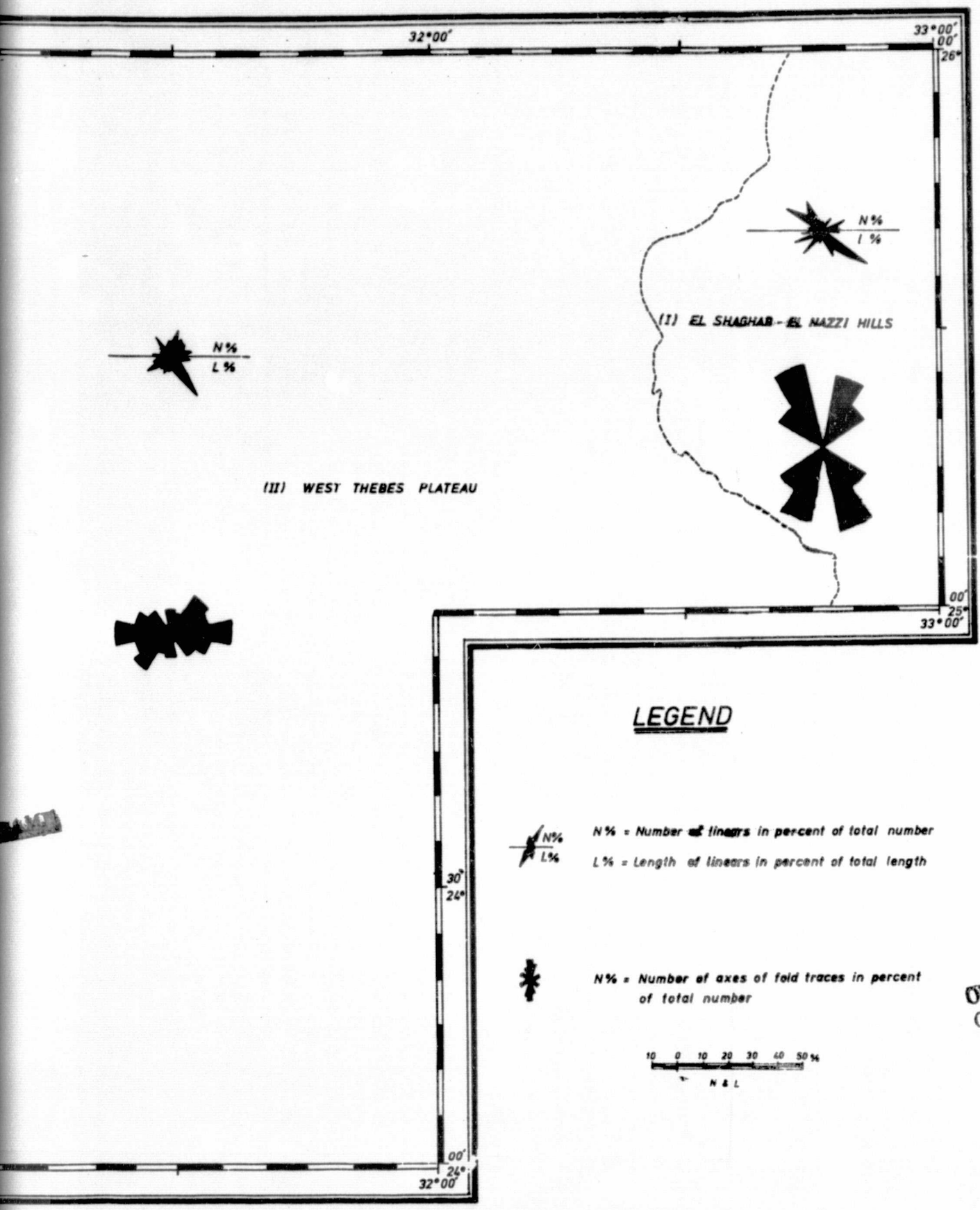
FIG.(5) AZIMUTH - FREQUENCY DIAGRAMS SHOWING TH

IN THE DIFFERENT GEOMORPHOLO

REQUENCY DIAGRAMS SHOWING THE DISTRIBUTION OF STRUCTURAL LINEA

IN THE DIFFERENT GEOMORPHOLOGIC UNITS OF THE KHARGA - DAKHLA OASI

20 15 10 5 0 10 20 30 40 50 60 70 80 90 100



LEGEND

N% = Number of linears in percent of total number

L% = Length of linears in percent of total length

N% = Number of axes of fold traces in percent of total number

10 0 10 20 30 40 50 %

N & L

3

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L LINEATIONS AND AXES OF FOLD TRACES

ILA OASES AREA, EGYPT.

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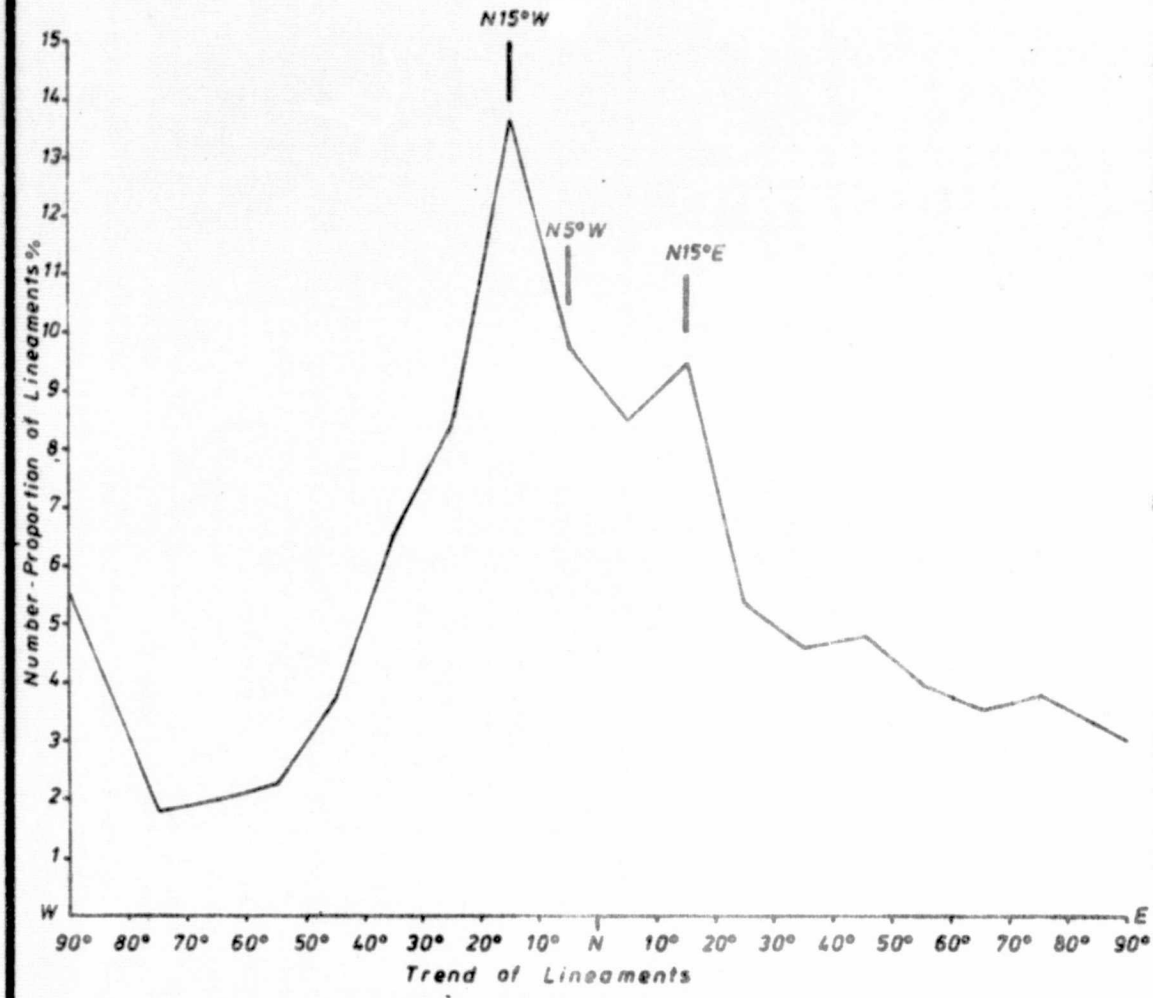

FIG.(6) FREQUNCY.CURVE SHOWING THE NUMBER - PROPORTION DISTRIBUTION OF STRUCTURAL LINEAMENTS IN THE KHARGA - DAKHLA OASES AREA.

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REMOTE SENSING RESEARCH PROJECT

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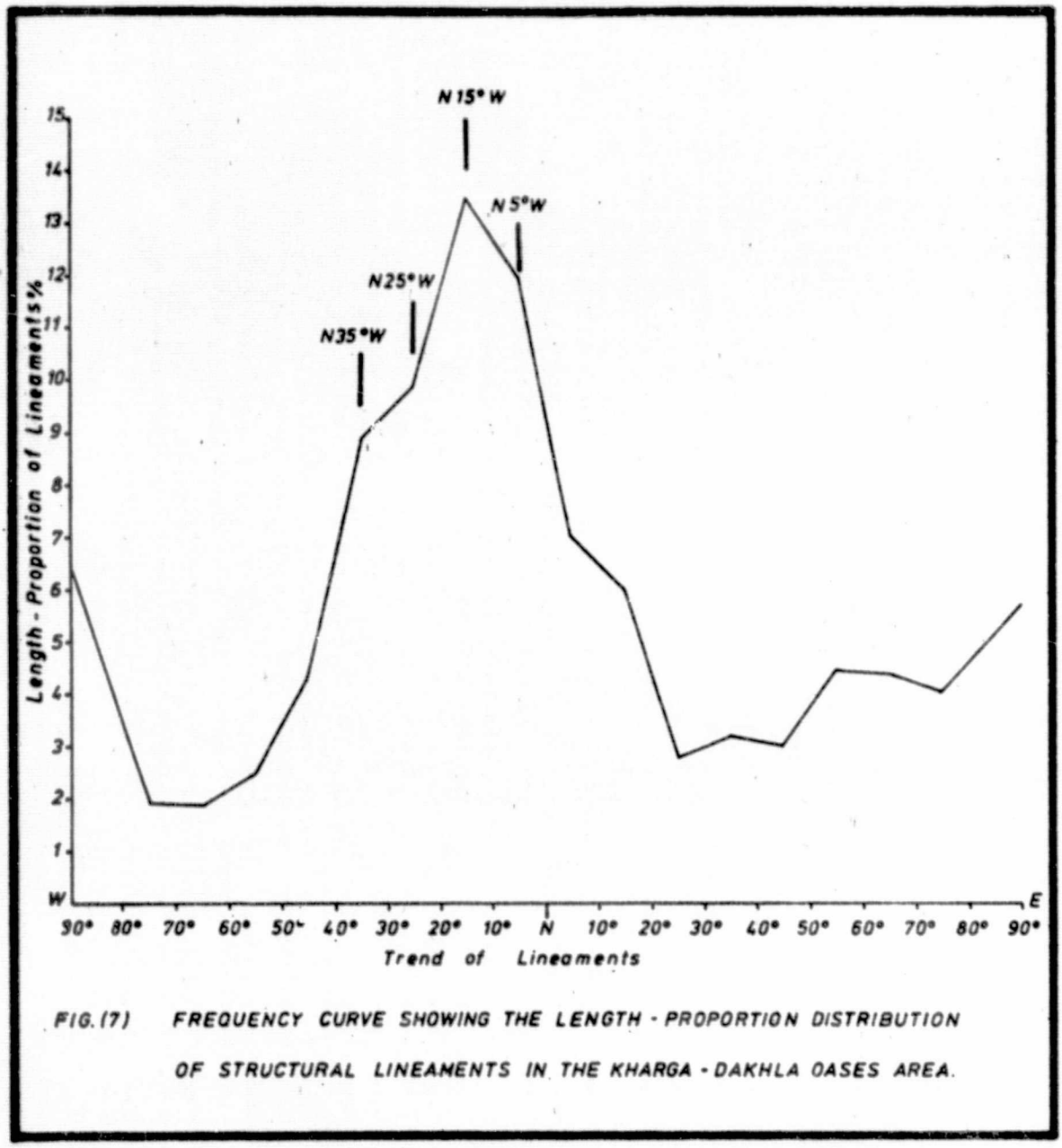

FIG. (7) FREQUENCY CURVE SHOWING THE LENGTH - PROPORTION DISTRIBUTION OF STRUCTURAL LINEAMENTS IN THE KHARGA - DAKHLA OASES AREA.

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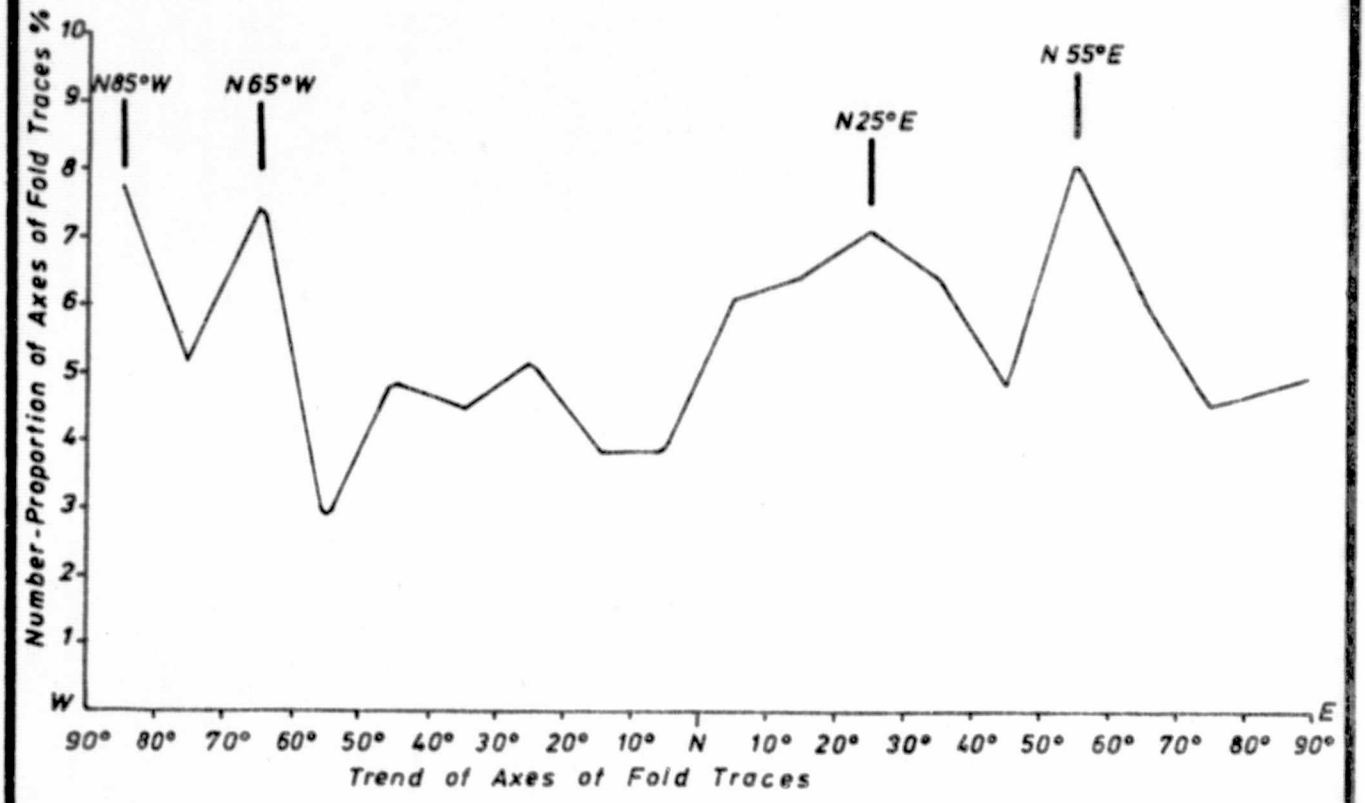

FIG.(8) FREQUENCY DISTRIBUTION CURVE FOR 310 AXES OF FOLD TRACES IN THE KHARGA - DAKHLA OASES AREA.

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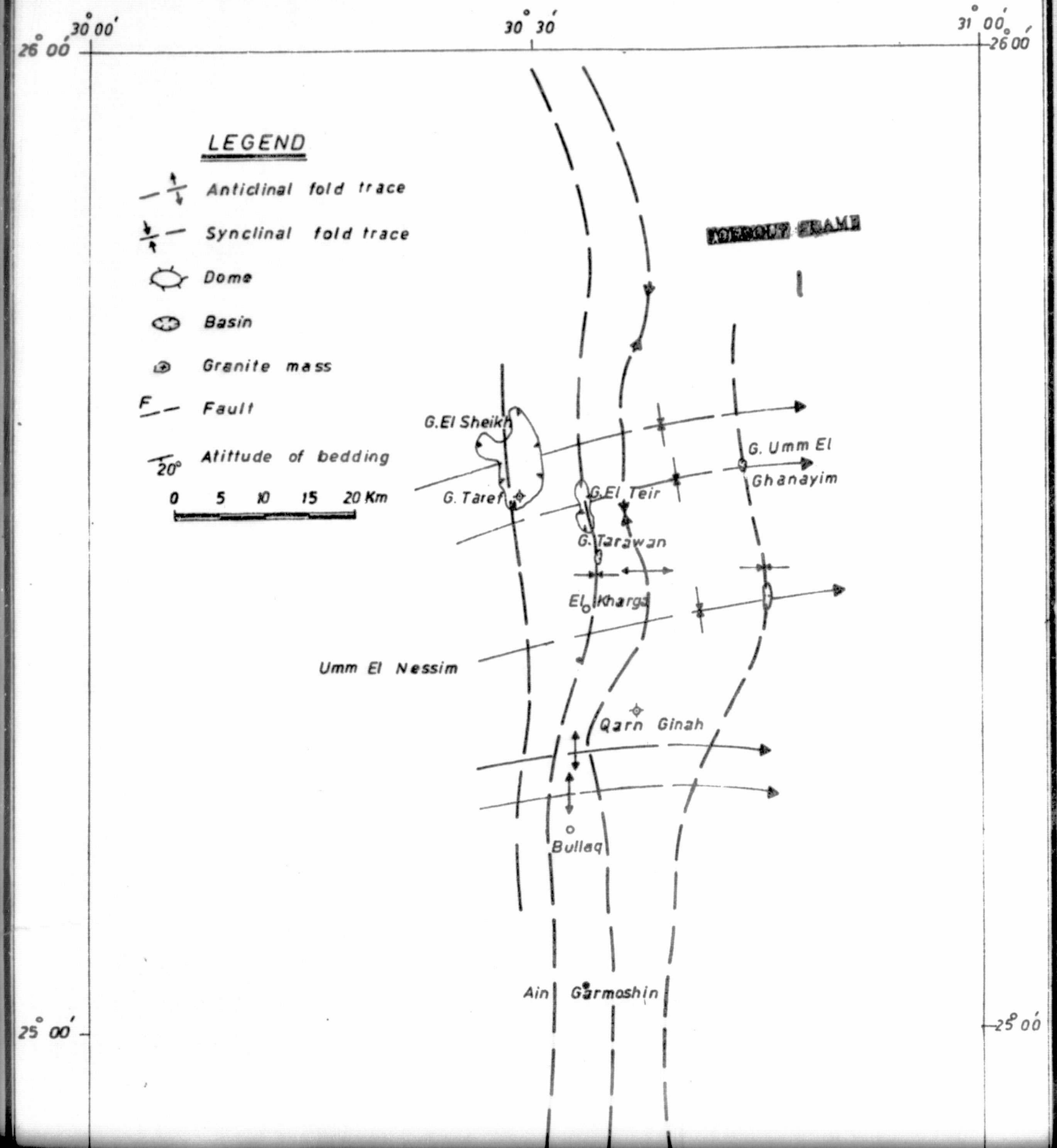


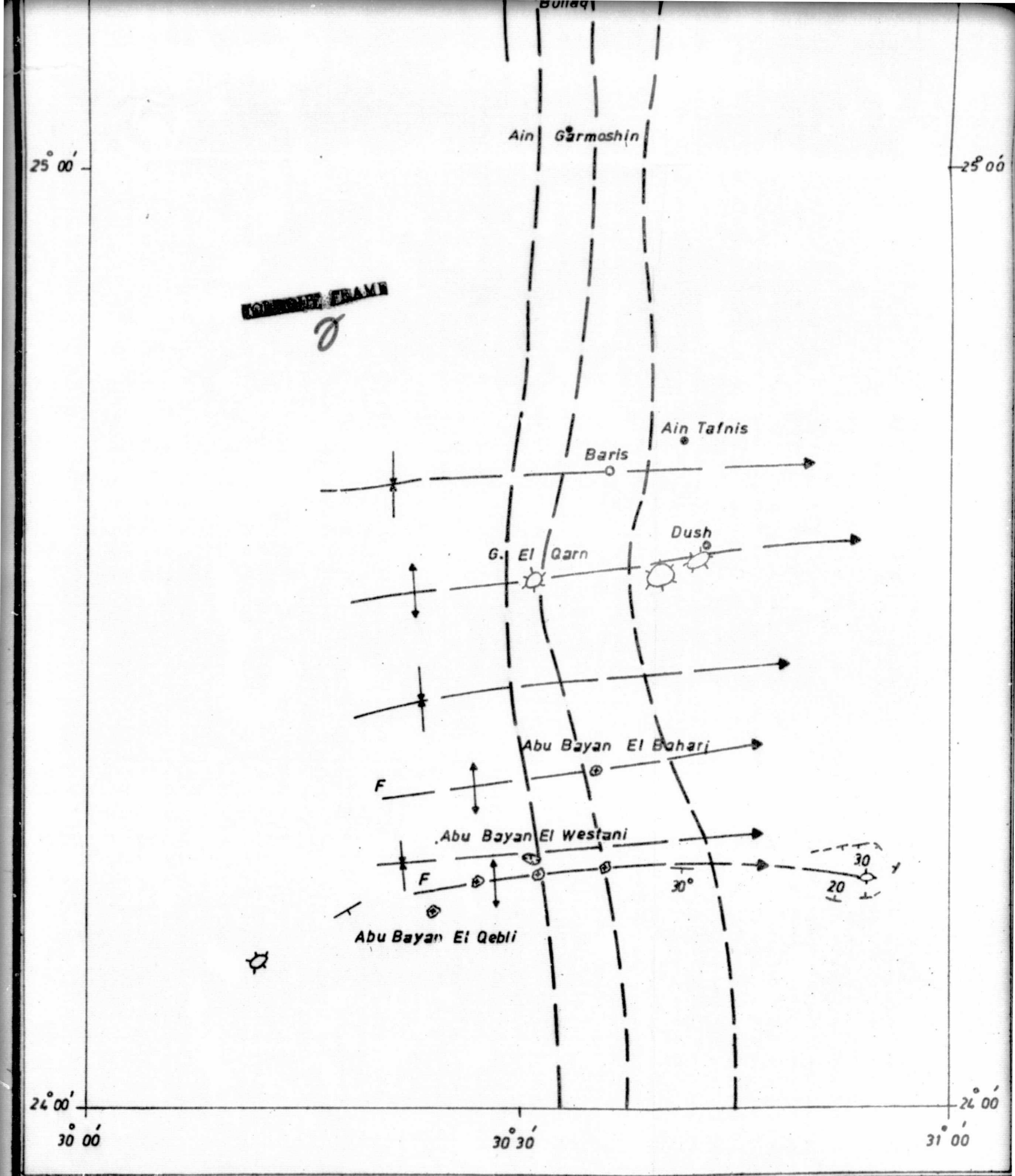
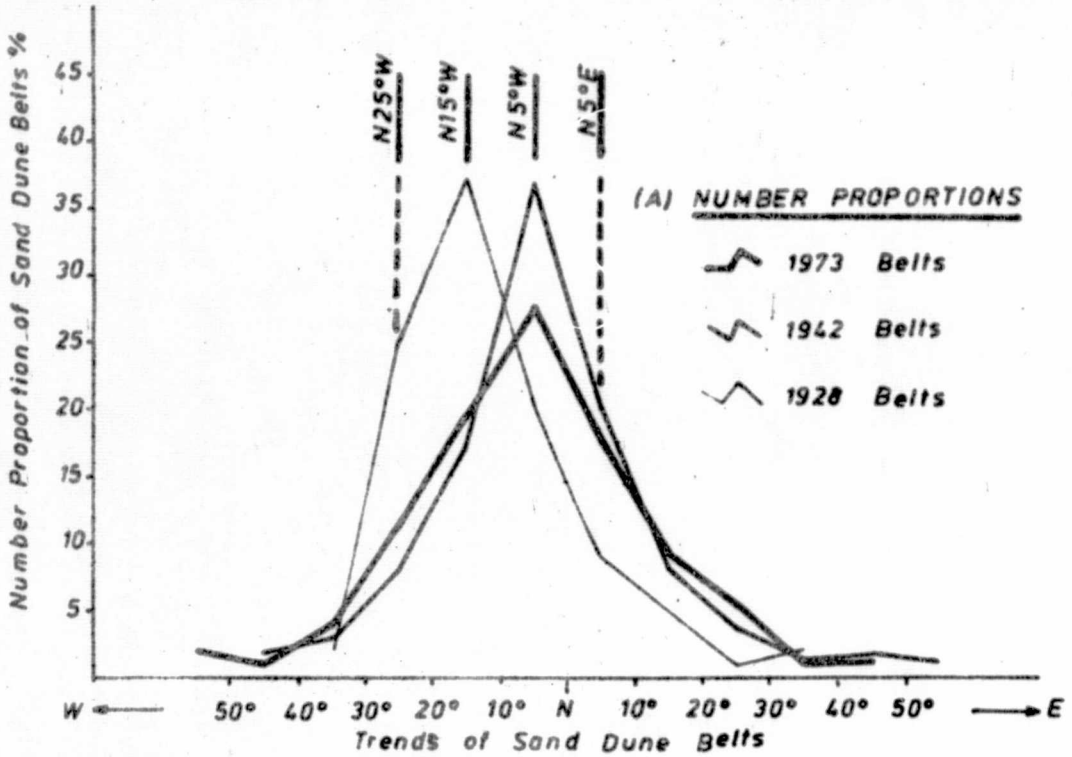


FIG.(9) SCHEMATIC STRUCTURAL MAP FOR KHARGA OASIS



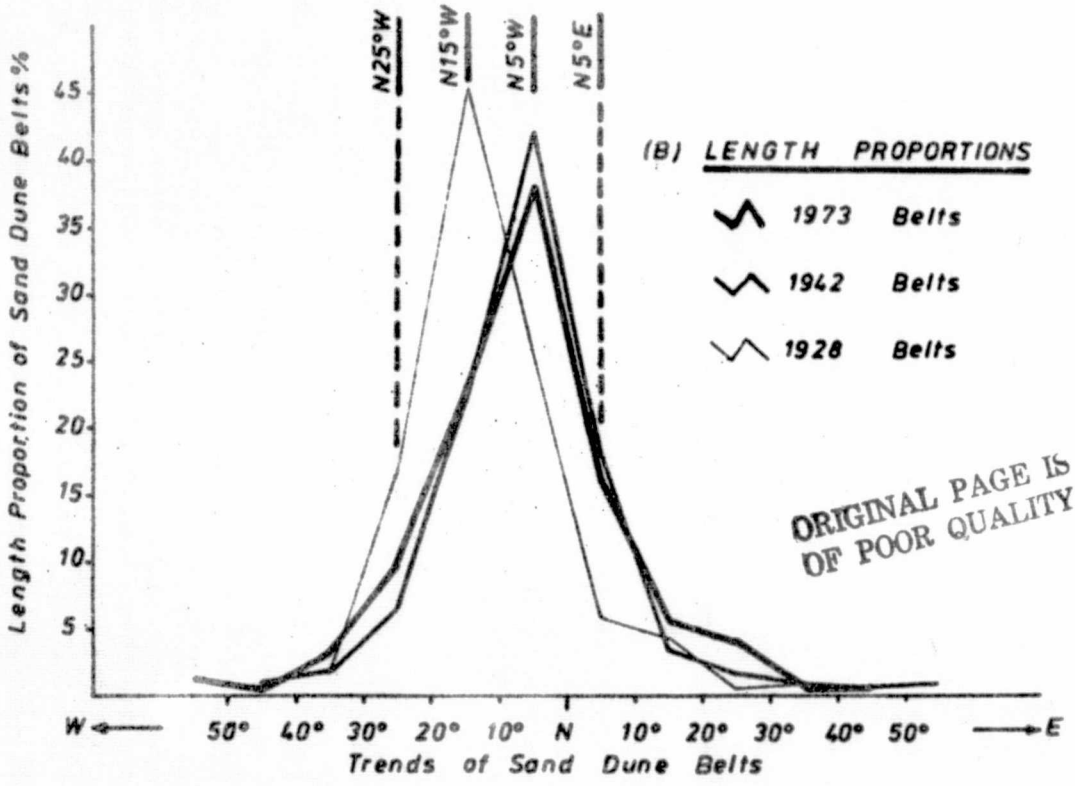


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FIG.(10) FREQUENCY DISTRIBUTION CURVES FOR THE NUMBER AND LENGTH PROPORTIONS OF THE MAIN SAND DUNE BELTS MAPPED IN THE KHARGA - DAKHLA OASES AREA AT VARIOUS YEARS.

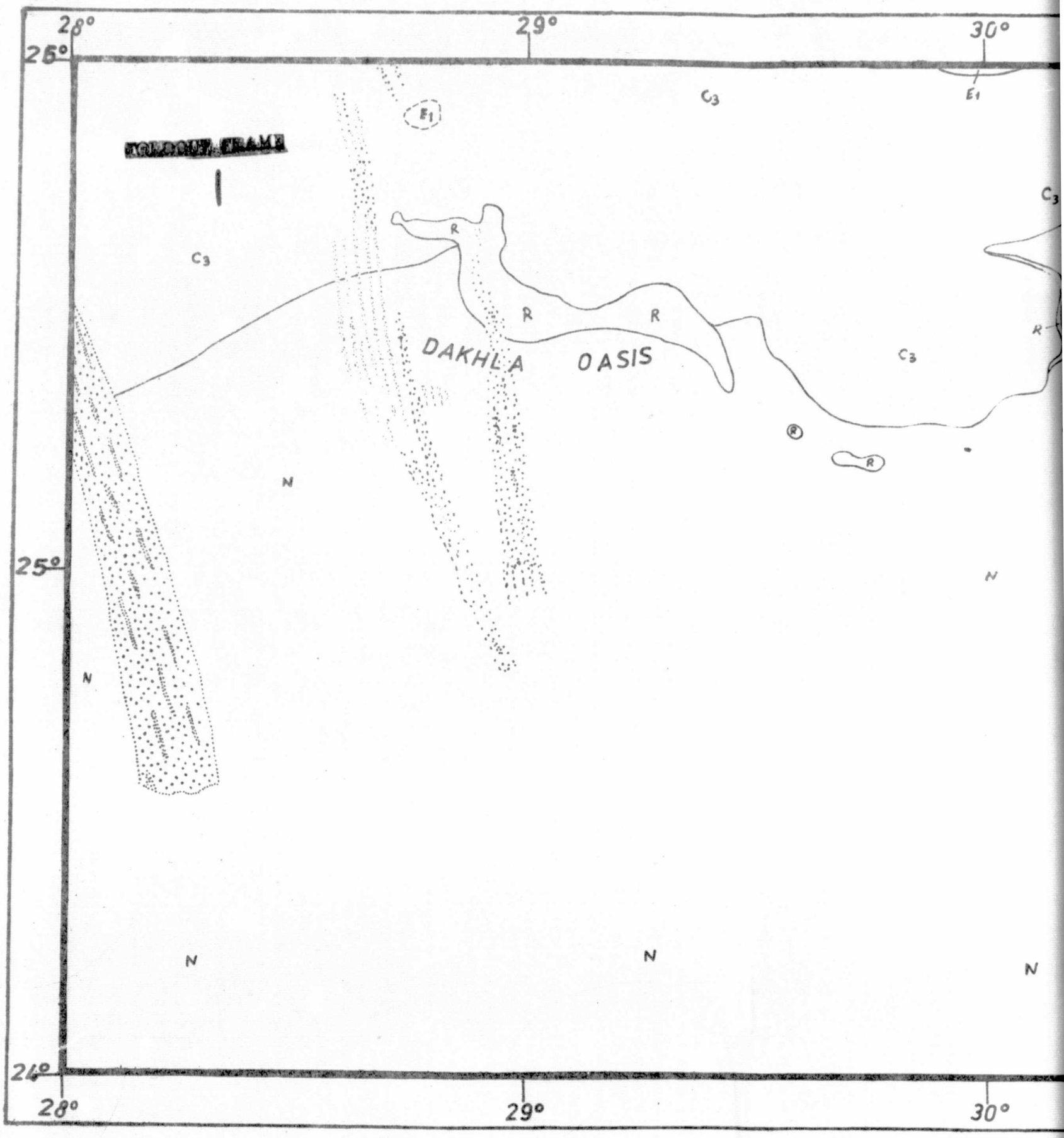
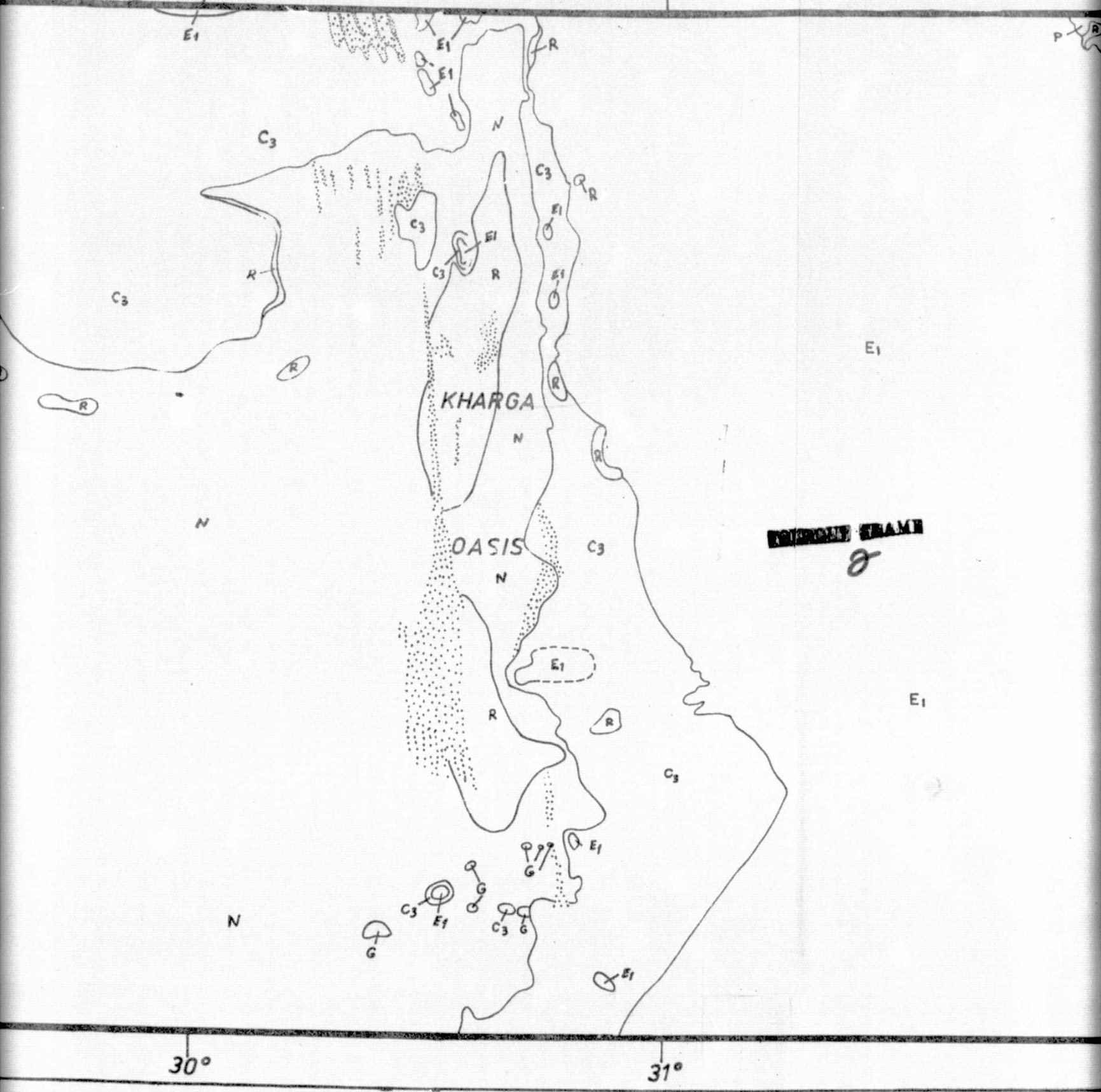


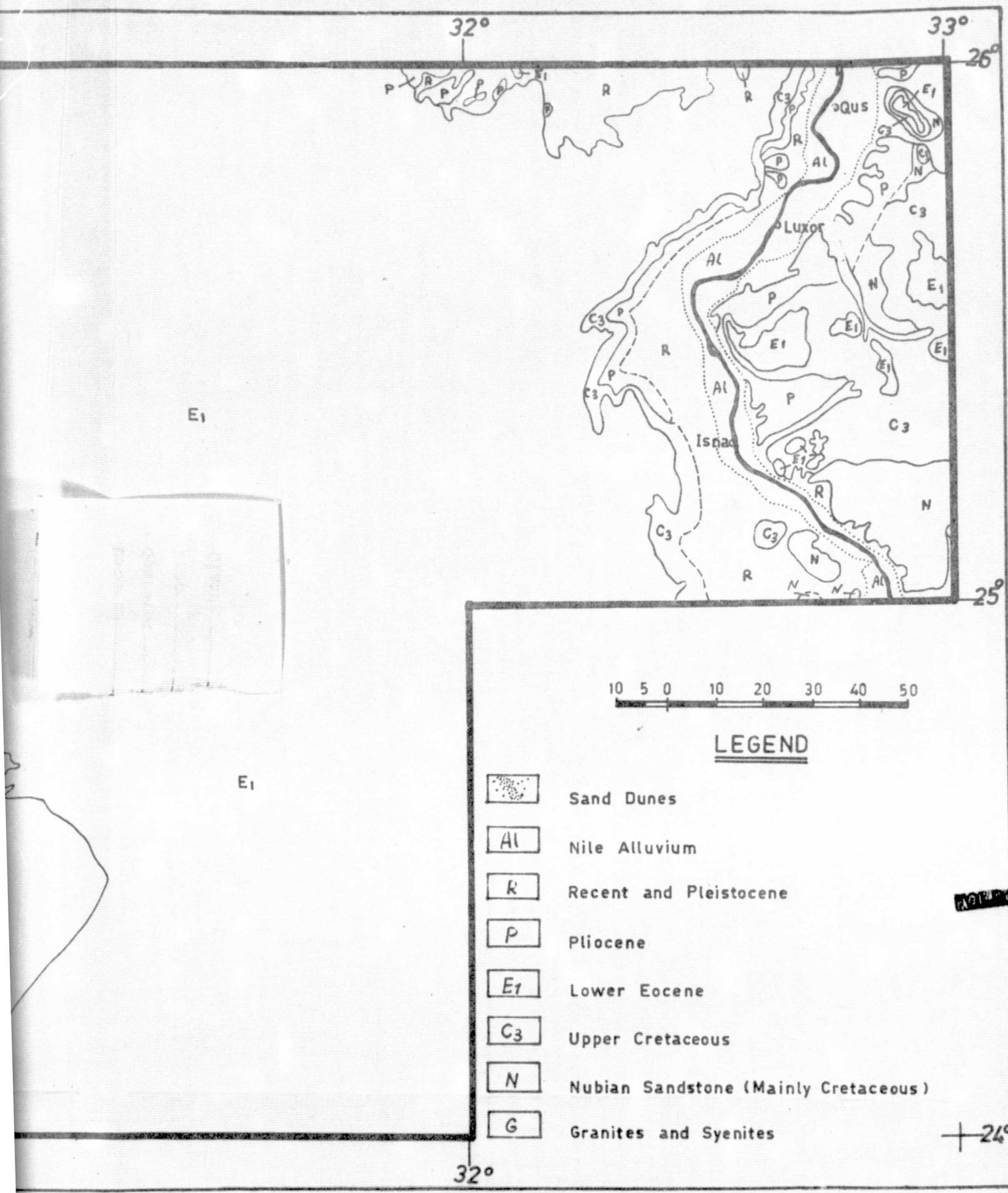
FIG.(11) PREVIOUS GEOLOGICAL MAP OF

(AFTER THE ATLAS OF EGYPT.



L MAP OF THE KHARGA - DAKHLA OASES AREA,

AS OF EGYPT, 1:1,000,000 - 1928)



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LA OASES AREA, EGYPT.

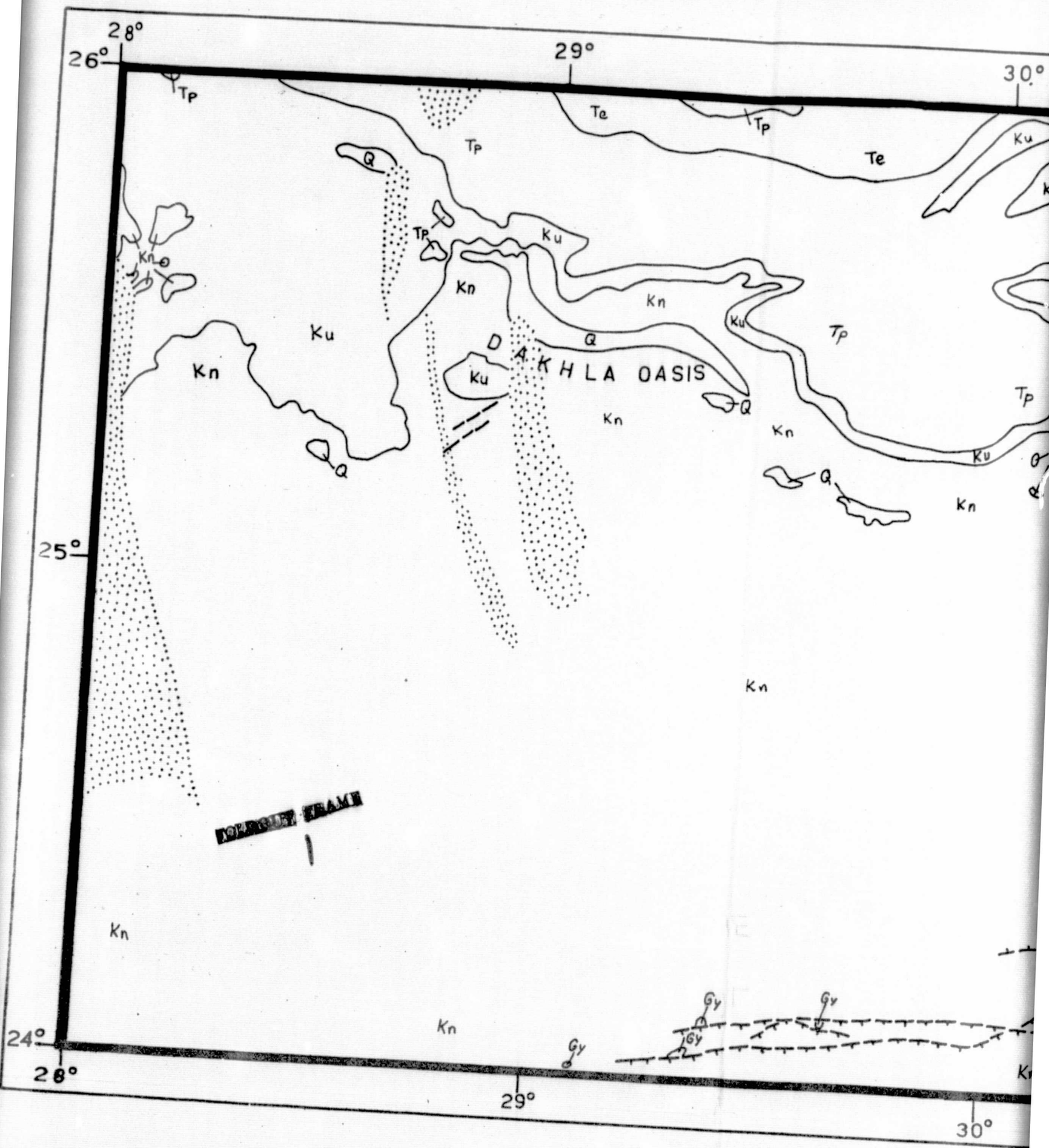
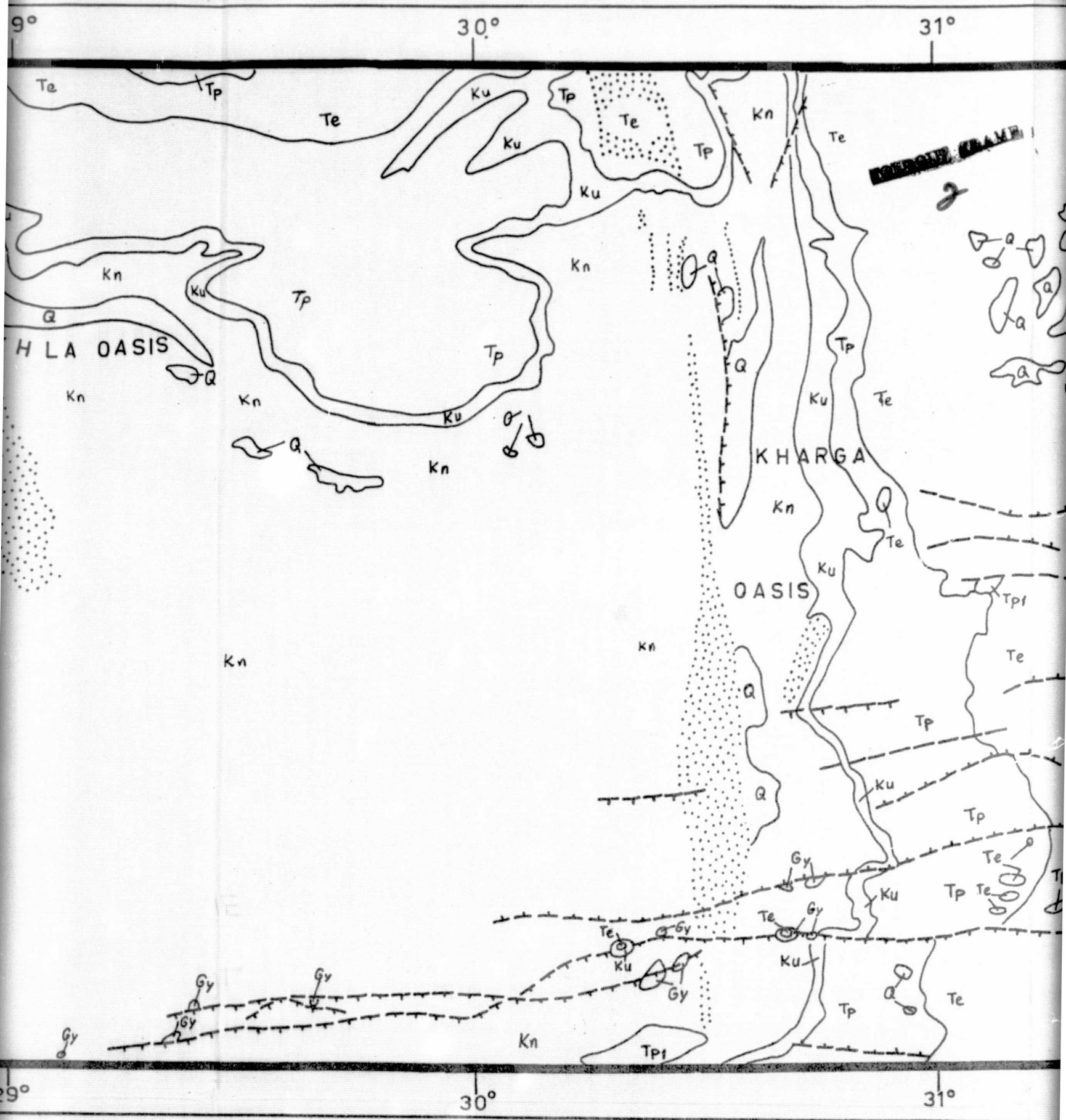
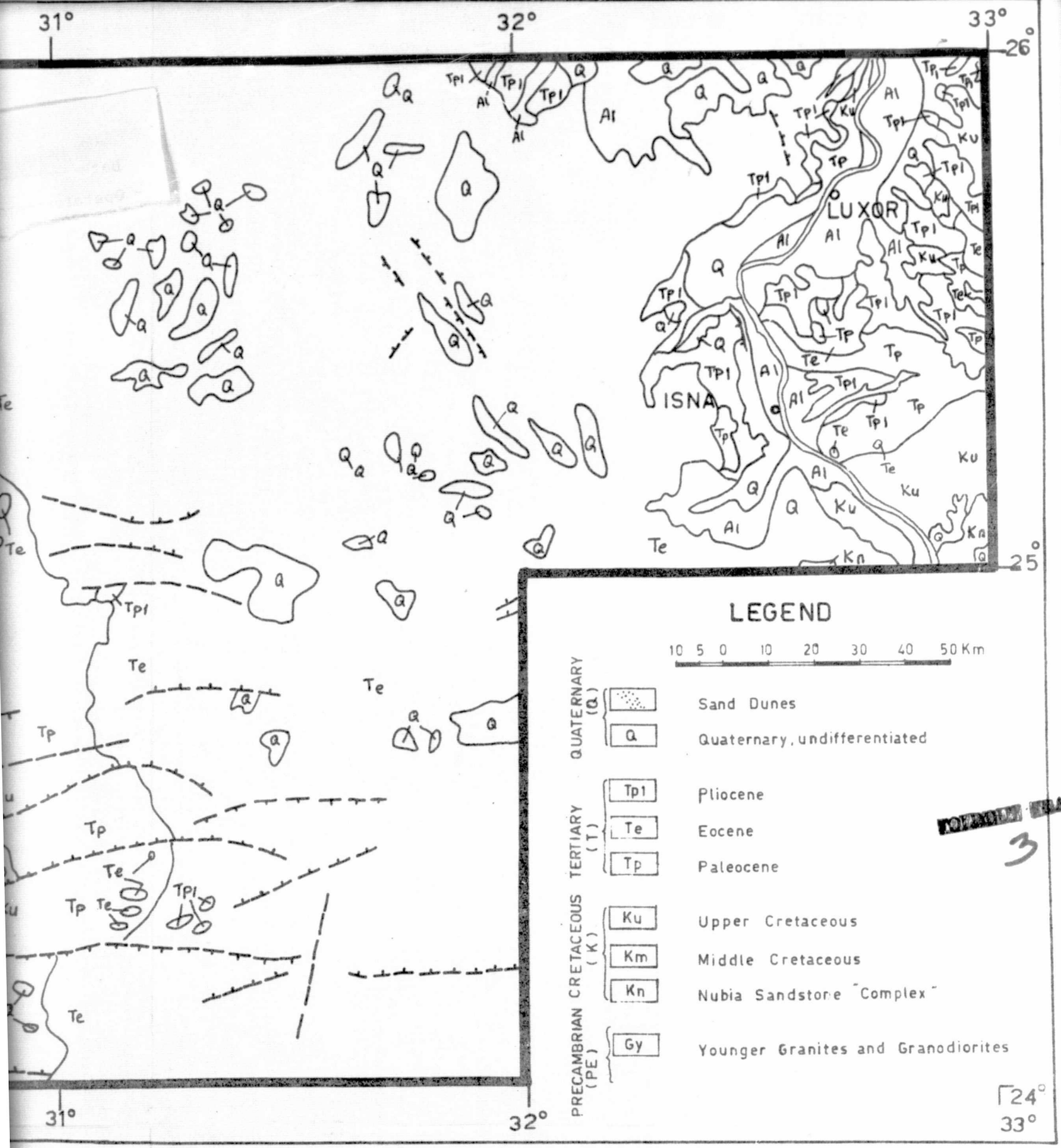


FIG.(12) COMPILED GEOLOGICAL MAP



LED GEOLOGICAL MAP OF THE KHARGA - DAK

(AFTER THE GEOLOGICAL MAP OF EGYPT, SCALE 1:2 000 0



GA - DAKHLA OASES AREA, EGYPT.

1:2,000,000 - 1971)